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POSTATTACK IMPACTS OF THE CRISIS RELOCATION STRATEGY ON TRANSPO--ETC(U)

SEP 78 J W BILLHEIMER, G FONDAHL, A W SIMPSON DCPA01-76-C-0317

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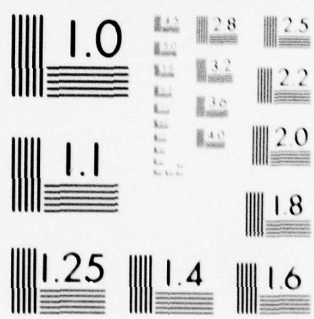

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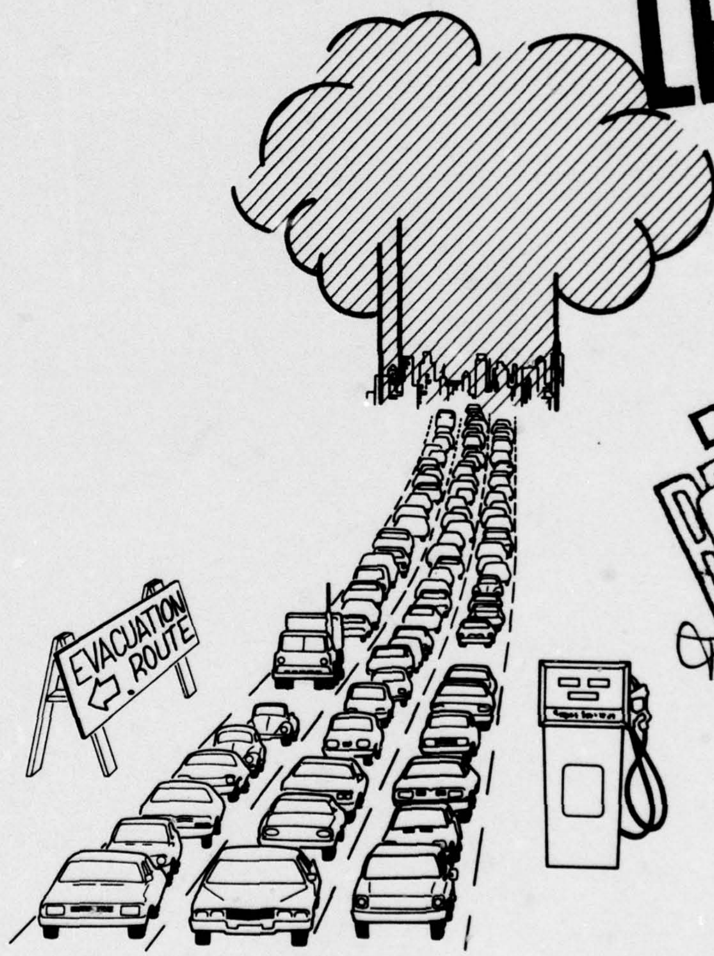
FINAL REPORT — VOLUME I

Postattack Impacts of the Crisis Relocation Strategy on Transportation Systems

ANALYSIS AND CASE STUDY



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September 1978

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FINAL REPORT

POSTATTACK IMPACTS OF THE CRISIS RELOCATION STRATEGY ON TRANSPORTATION SYSTEMS

Volume I: Analysis and Case Study

By:

John W. Billheimer
Gail Fondahl
Arthur W. Simpson

For:

Defense Civil Preparedness Agency
Washington, D.C. 20301
Contract DCPA01-76-C-0317
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SUMMARY

INTRODUCTION

Research undertaken in the mid-1960's assessed the effects of nuclear attack on components of the national transportation network under a strategy of in-place protection. More recent investigations have studied alternative strategies for transporting people and critical commodities from areas of high risk in anticipation of a nuclear attack. The current study extends the previous research by (1) investigating the effects of a nuclear attack on the reconfigured transportation system and the relocated population following an evacuation of high-risk areas, (2) identifying and evaluating alternative means of providing transportation system support to the relocated survivors of such an attack, and (3) reviewing existing relocation guidance in the light of probable postattack consequences. This research evaluates the problem of providing transportation system support following both a relocation effort and a nuclear attack, and systematically proposes and evaluates alternative solutions to this problem. Where applicable, the proposed solutions are examined in detail in a case study of Colorado Springs, Colorado.

PAST RESEARCH

Impacts of Crisis Relocation on Transportation Systems

Past studies have identified no potential transportation problems severe enough to render a crisis relocation strategy unworkable. The nationwide availability of vehicles far exceeds the anticipated demand, so that the chief limitations to the effective use of these vehicles are likely to be administrative problems of organization and deployment. The capability of local road networks will be stretched, particularly on the first day of relocation, but careful planning and scheduling coupled with the continuous monitoring and broadcasting of traffic conditions should enable these networks to handle the load in most U.S. cities.

Since the demand for motor fuel during and after relocation is not likely to exceed normal demand, the chief fuel problem will be one of redirecting the flow of gasoline from risk areas to host areas, so that supplies are available where they are needed and reserves may be built up in relatively invulnerable locations.

Past Postattack Research

Earlier studies of transportation system vulnerability under a strategy of in-place protection have indicated that the surviving aggregate inventories of critical transportation equipment, roadways, classification centers, and personnel will be more than adequate for the delivery of food and other essential goods and services. These studies indicate that damage to the U.S. fuel supply system would be relatively heavy, and that regional fuel imbalances could be a serious postattack problem.

Implications of Previous Research

While certain potential postattack problems may be alleviated by a relocation strategy, other problems will be intensified. The extensive vehicle movement and fuel stockpiling accompanying the relocation strategy will render both of these elements less vulnerable to nuclear attack. However, the survival of additional people in areas removed from traditional distribution centers can be expected to intensify the stress imposed on the damaged transportation system. Although the relocation itself will have no impact on the vulnerability of such fixed elements as the road network or fuel refineries, demands on these elements in the postattack period will be greatly affected by the relocation strategy. Damaged roadways will increase the transportation distances covered in providing critical supplies, and this additional distance, coupled with the survival of additional population, will create increased demands on surviving fuel refineries.

DAMAGE ASSESSMENT ANALYSIS

Under a crisis relocation strategy, approximately 98 percent of the Colorado Springs risk and host area population is expected to survive a nuclear attack. The comparable nationwide figure is 90 percent survival. These survivors will impose demands on three principal components of the national and local transportation system: vehicles, road and rail networks, and fuel.

Vehicle Survival

Vehicle availability is not expected to be a limiting factor on the movement of goods and people following an attack. In Colorado Springs, more than twice as many trucks, buses and locomotives will survive an attack following a crisis relocation strategy as are likely to survive under a strategy of in-place protection. To the extent possible, such critical vehicles as debris-removal equipment, switching locomotives, and dump trucks should be moved to the host area as part of the relocation effort, along with a supply of spare parts and maintenance manuals for all vehicles.

The most critical problem with transportation equipment under a crisis relocation strategy is likely to be one of organization and coordination. This is expected to be especially true following an attack. Although the surviving vehicle supply is expected to be more than adequate for carrying essential supplies, clear lines of authority and advance planning will be needed to ensure that the vehicles are in the right place at the right time with the right orders.

Road and Rail Network Survival.

Road Network. Key highway links were cut in every major city targeted in the postulated attack. Although past studies have determined that detour routings could be found around every damaged link, the current investigation estimated that such detours would increase travel times by factors ranging from 22 to 38 percent. Precise nationwide estimates of postattack travel distances and demands would require a model of nationwide commodity movement over the existing road network. Such a model was beyond the scope of the current study, but should be incorporated in future reserach efforts as a basis for assessing postattack travel distances, vehicle requirements, and fuel consumption.

Truckstops. In the two decades since they became a prominent part of the intercity transportation picture, the more than 3,000 truckstops located along the nation's highway system have proven themselves to be an invaluable source of emergency assistance to travelers and commercial truckers in natural disasters. Nearly 70 percent of these truckstops would survive a nuclear attack. The relative invulnerability of truckstops to nuclear attack, coupled with their importance in the day-to-day movement of intercity cargo make them a valuable resource in any crisis relocation plan. A companion report discusses the role of truckstops as traffic control centers under crisis relocation conditions. In addition to their traditional roles as fueling points, these control centers would also act as: (1) checkpoints for rerouting or reassignment of essential shipments; (2) interim consignment points for non-essential shipments; (3) relay points for drivers; (4) coordination and reassignment points for cabs and drivers; and (5) central assignment points for mechanics. To make maximum use of truckstops as an emergency resource, an attempt should be made to form a voluntary organization of truckstop owners capable of providing an emergency fueling capability for vehicles and havens of rescue for drivers and passengers in times of crisis.

Rail Network. If a nuclear attack were to occur, the nation's rail network would suffer heavy damage, with 41 percent of the classification yards and 53 percent of the repair shops surviving. It appears that the rail system could be 30 to 50 percent operational, but with reduced efficiency, within 30 days after the postulated attack. In general, damage and debris will cause considerable curtailment of rail service in the immediate postattack period, and a greater share of the nation's cargo will initially be carried by the more flexible trucking system.

In planning for postattack rail movement, key host-area terminals which could be used as control centers in time of crisis should be identified in the preattack period, and plans for the expansion and use of these terminals should be incorporated in appropriate crisis relocation planning documents. This has been accomplished for the Colorado Springs risk area. During the crisis relocation period, emergency power-generating equipment should be moved to these terminals, and rail panels for repairing track damage should be loaded on flatcars and spotted on sidings at various locations in the host area.

Fuel System Survival

An analysis of the damage to U.S. and Colorado petroleum production and distribution facilities indicates that severe fuel shortages would probably follow a nuclear attack. The destruction of national and local refineries, storage facilities, and pipelines would necessitate changing patterns of distribution and strict fuel use controls.

The two largest refineries located in Colorado and all Denver pipeline terminals would be severely damaged by the postulated attack, and would not be operational in the first postattack year. Nonetheless, up to 60 percent of colorado's preattack fuel supply could be transported by truck from undamaged supply points in Wyoming and Texas. At the national level, however, only 30 percent of U.S. refinery and storage capacity is expected to survive the postulated attack; therefore, it is anticipated that federal reallocations will effectively cut Colorado's fuel supply to 30 percent of preattack levels.

Following a crisis relocation prior to an attack, fuel requirements are expected to drop to between 35 and 40 percent of normal daily usage. As the nation's production capacity will far exceed consumption rates during this period, excess supplies should be stockpiled in host area storage tanks to alleviate anticipated postattack shortages. Rigid control and conservation measures such as rationing, vehicle impoundment, and restriction of unnecessary cargo shipments will be necessary following an attack. Introduction of these measures during the relocation period will allow these procedures to be tested under somewhat less harrowing ircumstances and increase the supply of fuel available for stockpiling. Critical petroleum production and distribution facilities on the fringes of anticipated target areas should be protected with sandbags, steel mesh, and earth embankments during the relocation period.

The available fuel supply will be the constraining element in the postattack management of the transportation system. In this regard, fuel shortages will be more critical than either vehicle losses or road damage. However, there should be sufficient fuel to support the movement of food and other essential commodities if its use is carefully controlled.

ANALYSIS OF AN EXTENDED CRISIS SITUATION

If the initial crisis relocation is not followed by an attack or a cessation of hostilities, an extended relocation may result in which risk area residents remain for relatively long periods of time within the host area. In the event such an extended relocation period occurs, several adjustments might be made in the relocation posture. For example, the number of critical industries and commuting workers might be increased, while some non-critical activities may be transplanted from the risk to the host area and restarted for the duration of the extended relocation period. At the same time, stockpiles of critical commodities could be amassed in the host area. Such adjustments could have poten-

tially large impacts on the transportation network and fuel supply system. As part of the current investigation, a range of adjustments associated with an extended relocation period was postulated, the transportation impacts of these adjustments were quantified, and alternatives for providing transportation support throughout the extended period were proposed and evaluated.

Analysis of the extended crisis situation in Colorado Springs indicated that none of the anticipated adjustments generated excessive transportation or fuel support requirements. An extended crisis period would provide additional time to stockpile fuel supplies in the host area, and it is strongly recommended that such a stockpiling strategy be followed. In Colorado Springs, secondary bulk storage facilities and gasoline station storage tanks would be filled to capacity in a little more than one week following the completion of relocation. It is likely, then, that a strategy of fuel stockpiling under extended crisis conditions will require the creation of additional fuel storage capability in host areas. Construction of traditional bulk storage facilities would require several months. Possible alternatives for providing such additional storage in a shorter time period include:

- Filling the tanks of impounded automobiles;
- Building expedient storage facilities using collapseable rubber-plastic containers in earthern embankments; and
- Using underground storage.

In addition to fuel, food supplies such as dried milk, canned meat products, and raw grain likely to be in short supply or geographically inaccessible following an attack should be stockpiled in host areas under extended crisis conditions.

IMPLICATIONS OF POSTATTACK RESEARCH ON CRISIS RELOCATION GUIDANCE

The results of the postattack research on the Colorado Springs study area have been reviewed in light of the current guidance for crisis relocation planning. As a result of this review, it appears that the basic strategy proposed for providing transportation under crisis relocation conditions is sound, although certain changes and additions are recommended. The analysis accompanying the damage assessment and evaluation procedures brought to light several elements which should be included in the crisis relocation guidance issued by the federal government and in the crisis relocation plans for specific areas. These elements include:

1. Provision for moving critical vehicles (such as switch engines and debris-removal equipment) out of risk areas where possible, and assembling parts inventories within the host areas;

2. Guidelines for identifying key host area railyards and planning for their expansion;

3. Guidelines for preparing a list of critical pipeline repair facilities and plans to protect them;

4. Provision for stockpiling fuel as soon as possible during crisis relocation, for constructing expedient bulk storage facilities within the host area, and for supporting plans for peacetime crude stockpiles and research into expedient storage structures and product storage; and

5. Provision for identifying key host- and risk-area truckstops, outlining the role of these truckstops under crisis relocation conditions, and forming a peacetime organization of truckstop owners.

These elements, along with general postattack guidance for transportation system management, have been incorporated in prototype crisis relocation plans for the State of Colorado, the risk area of El Paso County, and a sample host area, Fremont County. Guidelines for state and local relocation planners have been updated to reflect these elements, as well as other concerns identified in extensive interviews with planners and industry personnel. A summary of the revised guidelines appears in the accompanying exhibit.

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EXHIBIT S.1

RECOMMENDED GUIDELINES FOR TRANSPORTATION SUPPORT OF THE CRISIS RELOCATION STRATEGY

STATE AND REGIONAL ACTIVITIES

- Revise fuel distribution patterns from secondary sources to the consumer
- Arrange for additional drivers and equipment needed to distribute food, fuel, & other critical items.
- Waive vehicle highway weight restrictions
- Publicize revised regulations and chain of command.

	GENERAL GUIDELINES	RISK AREA ACTIVITIES	HOST AREA ACTIVITIES
POPULATION MOVEMENT	• Most evacuees will relocate in private automobiles. • Autoless residents should proceed to nearest school or polling place in accordance with publicized schedules.	• Evacuees with autos should maximize vehicle occupancy & schedule departures to minimize likelihood of congestion. • Local buses should operate on reduced holiday schedules during early stages of relocation. Remainder of fleet will be used in evacuation. In most cities, school buses, public transit, & local tour buses will be adequate to relocate autoless residents; intercity buses should be directed to cities with vehicle shortages. Bus departures should be scheduled to minimize congestion. • Rail passenger service should be used where possible. Heavy trucks and boxcars can supplement evacuation vehicle fleet in cases of extreme emergency.	• Use of private autos will be restricted once host area is reached. • Following relocation, risk area buses will provide public transportation capability in host area. • Buses & carpools should be used to extent possible in commuting of critical workers.
CARGO MOVEMENT	• Intercity cargo flow will generally follow normal patterns, with movements restricted to critical goods. • Local cargo flow will be restricted to movement of critical goods, but travel distances will be increased, increasing requirements for vehicles & drivers carrying critical commodities. • Specialized motor vehicles (e.g., ambulances, dump trucks, debris-removal equipment) and critical rail rolling stock will be evacuated to host areas; spare parts will be stockpiled in safe locations	• Continue to operate all major fuel wholesale operations, primary & secondary fuel storage terminals, & other distribution facilities for critical commodities. • Augment vehicle fleet & driver pool for transportation of critical goods as required, following guidelines & procedures established by NDTA for obtaining personnel & equipment from less critical sectors. • Increase vehicle & driver productivity by taking advantage of waived restrictions & weight limitations; minimizing down time; relaxing maintenance requirements; increasing vehicle loads; loading only full pallet quantities; & shipping only necessary commodities. • Relocate specialized motor vehicles, critical rolling stock and repair equipment to host areas.	• Continue all warehousing & distribution activities for critical goods, expanding operations where possible through use of commandeered space, worker overtime, & relocated workers. • Augment transportation fleet & driver pool as required, following guidelines and procedures established by NDTA for obtaining personnel & new equipment from other sectors. • Increase vehicle & driver productivity by taking advantage of waived driver restrictions & weight limitations; minimizing down time; relaxing maintenance requirements; increasing vehicle loads; loading only full pallet quantities; & shipping only necessary commodities. • Stockpile vehicle parts and maintenance manuals.
ROAD NETWORK UTILIZATION	• Advance planning should identify bottlenecks & use all available roads to maximize outbound flow. Effects of congestion on road capacity should be explicitly considered, & contingency plans should be developed to bypass congested bottlenecks. • Traffic flow should be monitored throughout relocation period, preferably by helicopter. • Police & emergency rescue vehicles should patrol evacuation routes to remove disabled vehicles.	• All available means should be employed to persuade population to limit number of vehicles used in evacuation & spread departures evenly over three-day relocation period. • Frequent reports on traffic conditions should be provided throughout the relocation period to allow departing evacuees to enter traffic flow streams at optimal times & to permit motorists to adjust travel plans en route. • Where the possibility of congestion is high, license plate controls should be used to schedule departures. • Move rail panels to host area on flatcars.	• Reception stations should remain open around the clock to facilitate spreading of risk area departure times. • Service stations & rest areas will serve as staging points for emergency vehicle patrols during relocation. • Identify key host area terminals (truckstops and railyards) in advance and plan for their support.
FUEL CONTROL AND DISTRIBUTION	• If fuel shortages do not exist prior to relocation, they are not likely to occur during or after relocation. However, rationing & other point-of-purchase controls may be desirable to conserve fuel against the shortages that can be expected if an attack ensues. • The flow of motor fuel will be redirected from risk area terminals & stations to host area bulk terminals & gas stations. • Intercompany fuel transfers should be permitted to facilitate the redirection of flow from risk to host areas. • To the extent possible, vehicles moving between risk & host areas with critical workers & commodities should refuel in the risk area. • Restrictions on the use of leaded fuel should be eliminated. • Excess fuel produced during relocation period should be stockpiled in host areas.	• Secondary bulk terminals and pipeline outlets will continue to operate to supply host area stations & terminals & critical risk area stations. Once the relocation order is given, only a limited number of critical stations will be resupplied. Where possible, risk area pipeline outlets should supply these stations. • All gasoline stations should remain open around the clock during three-day relocation period until their tanks are drained. Following relocation, only critical stations will remain open. • Non-critical stations with fuel remaining following relocation should deposit keys with public safety officials so that inventories can be used to support movement of critical workers & commodities. • Stations should observe rationing controls & odd/even regulations established nationally during pre-crisis period & evacuation period. • Strengthen critical pipeline terminals and refineries on fringes of target area against attack.	• Supplies to stations along evacuation routes will be bolstered. These stations should remain open around the clock during relocation. • Where appropriate, host area pipeline terminals should be used to advantage in diverting flow of motor fuel. • Following relocation, deliveries to bulk terminals & gasoline stations will be stepped up to meet relocated demand & to develop fuel stockpiles in less vulnerable locales. • Stations should observe rationing controls, odd/even regulations, & any purchase restrictions established nationally before & after relocation. • Construct expedient fuel storage facilities where necessary.

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6 POSTATTACK IMPACTS OF THE CRISIS RELOCATION STRATEGY ON TRANSPORTATION SYSTEMS.

Volume I. Analysis and Case Study.

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This study extends previous research into the transportation implications of a crisis relocation by (1) investigating the effects of a nuclear attack on the reconfigured transportation system and the relocated population, (2) identifying and evaluating alternative means of providing transportation system support to the relocated survivors of such an attack, and over

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(3) reviewing existing relocation guidance in the light of probable postattack consequences. This research evaluates the problem of providing transportation system support following both a relocation effort and a nuclear attack, and systematically proposes and evaluates alternative solutions to this problem. Where applicable, the proposed solutions are examined in detail in a case study of Colorado Springs, Colorado.

The study addresses the principal components of the transportation system: vehicles, road and rail networks, and fuel. More than enough vehicles are expected to survive an attack to meet essential transportation needs, although problems of organization and coordination can be anticipated. Key highway links will be cut in every major city. In most instances, detour routes will survive, although their use will increase postattack travel distances by as much as 40 percent. The nationwide network of truckstops is relatively invulnerable to a population-based attack, and is expected to be a valuable resource during and after an evacuation. Damage and debris will cause considerable curtailment of rail service in the immediate postattack period, and a greater share of the nation's cargo will initially be carried by the more flexible trucking system.

Severe fuel shortages can be anticipated following a nuclear attack, and these shortages will be more critical than either vehicle losses or road and rail network damage in constraining postattack movement. However, there should be sufficient fuel to support the movement of food and other essential commodities if its use is carefully controlled.

On the basis of the case study, the transportation elements of prototype crisis relocation plans for the State of Colorado, the Colorado Springs area, and a representative reception area (Fremont County, Colorado) have been revised and updated to reflect postattack concerns. Guidelines for state and local relocation planners in other areas have been similarly updated.

PREFACE

This report was prepared as part of a series of concurrent studies undertaken by the Defense Civil Preparedness Agency to investigate the potential planning and implementation problems associated with a crisis relocation strategy designed to transfer populations from high-risk areas during periods of severe international crisis. The report was prepared under Contract DCPA01-76-C-0317, and addresses the problems incurred in providing transportation support to survivors of a nuclear attack preceded by a crisis relocation. The research described in the report was accomplished over a one and one-half year period in the Los Altos, California offices of SYSTAN, Inc. under the direction of Dr. John W. Billheimer, with assistance from Mr. Arthur Simpson and Ms. Gail Fondahl. Mr. Simpson was responsible for assembling information on the existing road, rail and fuel distribution networks, and assessing nuclear attack damage at national and local levels. Ms. Fondahl helped to assemble and interpret data on road networks, and developed simplified procedures for computing transportation stress. Mr. Ed Slibeck of the National Transportation Fueling Corporation provided invaluable information on truckstops, while Ms. Carole Parker organized and edited the final report.

In serving as technical monitor on the project, Mr. Steve Birmingham of DCPA provided technical guidance throughout the investigation, and helped to establish convenient avenues of liaison with concurrent crisis relocation studies. At the national level, Mr. George Van den Berghe and Mr. Hanford Edsall of DCPA also supplied useful guidance, while Mr. Frank Mollner of DCPA Region VI provided valuable background information on the Colorado Springs Study Area.

This research on "Postattack Impacts of the Crisis Relocation Strategy on Transportation Systems" is reported in four volumes:

Volume I: Analysis and Case Study

Volume II: Revised Planning Guidelines

Volume III: The Role of Truckstops in Crisis Relocation

Volume IV: Prototype Plans for State of Colorado, El Paso County and Fremont County (limited distribution)

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An analysis of the damage to U.S. and Colorado petroleum production and distribution facilities indicates that severe fuel shortages would probably follow a nuclear attack. The destruction of national and local refineries, storage facilities, and pipelines would necessitate changing patterns of distribution and strict fuel use controls.

The two largest refineries located in Colorado and all Denver pipeline terminals would be severely damaged by the postulated attack, and would not be operational in the first postattack year. Nonetheless, up to 60 percent of colorado's preattack fuel supply could be transported by truck from undamaged supply points in Wyoming and Texas. At the national level, however, only 30 percent of U.S. refinery and storage capacity is expected to survive the postulated attack; therefore, it is anticipated that federal reallocations will effectively cut Colorado's fuel supply to 30 percent of preattack levels.

Following a crisis relocation prior to an attack, fuel requirements are expected to drop to between 35 and 40 percent of normal daily usage. As the nation's production capacity will far exceed consumption rates during this period, excess supplies should be stockpiled in host area storage tanks to alleviate anticipated postattack shortages. Rigid control and conservation measures such as rationing, vehicle impoundment, and restriction of unnecessary cargo shipments will be necessary following an attack. Introduction of these measures during the relocation period will allow these procedures to be tested under somewhat less harrowing ircumstances and increase the supply of fuel available for stockpiling. Critical petroleum production and distribution facilities on the fringes of anticipated target areas should be protected with sandbags, steel mesh, and earth embankments during the relocation period.

The available fuel supply will be the constraining element in the postattack management of the transportation system. In this regard, fuel shortages will be more critical than either vehicle losses or road damage. However, there should be sufficient fuel to support the movement of food and other essential commodities if its use is carefully controlled.

ANALYSIS OF AN EXTENDED CRISIS SITUATION

If the initial crisis relocation is not followed by an attack or a cessation of hostilities, an extended relocation may result in which risk area residents remain for relatively long periods of time within the host area. In the event such an extended relocation period occurs, several adjustments might be made in the relocation posture. For example, the number of critical industries and commuting workers might be increased, while some non-critical activities may be transplanted from the risk to the host area and restarted for the duration of the extended relocation period. At the same time, stockpiles of critical commodities could be amassed in the host area. Such adjustments could have poten-

tially large impacts on the transportation network and fuel supply system. As part of the current investigation, a range of adjustments associated with an extended relocation period was postulated, the transportation impacts of these adjustments were quantified, and alternatives for providing transportation support throughout the extended period were proposed and evaluated.

Analysis of the extended crisis situation in Colorado Springs indicated that none of the anticipated adjustments generated excessive transportation or fuel support requirements. An extended crisis period would provide additional time to stockpile fuel supplies in the host area, and it is strongly recommended that such a stockpiling strategy be followed. In Colorado Springs, secondary bulk storage facilities and gasoline station storage tanks would be filled to capacity in a little more than one week following the completion of relocation. It is likely, then, that a strategy of fuel stockpiling under extended crisis conditions will require the creation of additional fuel storage capability in host areas. Construction of traditional bulk storage facilities would require several months. Possible alternatives for providing such additional storage in a shorter time period include:

- Filling the tanks of impounded automobiles;

- Building expedient storage facilities using collapseable rubber-plastic containers in earthern embankments; and

- Using underground storage.

In addition to fuel, food supplies such as dried milk, canned meat products, and raw grain likely to be in short supply or geographically inaccessible following an attack should be stockpiled in host areas under extended crisis conditions.

IMPLICATIONS OF POSTATTACK RESEARCH ON CRISIS RELOCATION GUIDANCE

The results of the postattack research on the Colorado Springs study area have been reviewed in light of the current guidance for crisis relocation planning. As a result of this review, it appears that the basic strategy proposed for providing transportation under crisis relocation conditions is sound, although certain changes and additions are recommended. The analysis accompanying the damage assessment and evaluation procedures brought to light several elements which should be included in the crisis relocation guidance issued by the federal government and in the crisis relocation plans for specific areas. These elements include:

1. Provision for moving critical vehicles (such as switch engines and debris-removal equipment) out of risk areas where possible, and assembling parts inventories within the host areas;

2. Guidelines for identifying key host area railyards and planning for their expansion;

3. Guidelines for preparing a list of critical pipeline repair facilities and plans to protect them;

4. Provision for stockpiling fuel as soon as possible during crisis relocation, for constructing expedient bulk storage facilities within the host area, and for supporting plans for peacetime crude stockpiles and research into expedient storage structures and product storage; and

5. Provision for identifying key host- and risk-area truckstops, outlining the role of these truckstops under crisis relocation conditions, and forming a peacetime organization of truckstop owners.

These elements, along with general postattack guidance for transportation system management, have been incorporated in prototype crisis relocation plans for the State of Colorado, the risk area of El Paso County, and a sample host area, Fremont County. Guidelines for state and local relocation planners have been updated to reflect these elements, as well as other concerns identified in extensive interviews with planners and industry personnel. A summary of the revised guidelines appears in the accompanying exhibit.

EXHIBIT S.1

RECOMMENDED GUIDELINES FOR TRANSPORTATION SUPPORT OF THE CRISIS RELOCATION STRATEGY

STATE AND REGIONAL ACTIVITIES

- Revise fuel distribution patterns from secondary sources to the consumer
- Arrange for additional drivers and equipment needed to distribute food, fuel, & other critical items.
- Waive vehicle highway weight restrictions
- Publicize revised regulations and chain of command

	GENERAL GUIDELINES	RISK AREA ACTIVITIES	HOST AREA ACTIVITIES
POPULATION MOVEMENT	• Most evacuees will relocate in private automobiles. • Autoless residents should proceed to nearest school or polling place in accordance with publicized schedules.	• Evacuees with autos should maximize vehicle occupancy & schedule departures to minimize likelihood of congestion. • Local buses should operate on reduced holiday schedules during early stages of relocation. Remainder of fleet will be used in evacuation. In most cities, school buses, public transit, & local tour buses will be adequate to relocate autoless residents; intercity buses should be directed to cities with vehicle shortages. Bus departures should be scheduled to minimize congestion. • Rail passenger service should be used where possible. Heavy trucks and boxcars can supplement evacuation vehicle fleet in cases of extreme emergency.	• Use of private autos will be restricted once host area is reached. • Following relocation, risk area buses will provide public transportation capability in host area. • Buses & carpools should be used to extent possible in commuting of critical workers.
CARGO MOVEMENT	• Intercity cargo flow will generally follow normal patterns, with movements restricted to critical goods. • Local cargo flow will be restricted to movement of critical goods, but travel distances will be increased, increasing requirements for vehicles & drivers carrying critical commodities. • Specialized motor vehicles (e.g., ambulances, dump trucks, debris-removal equipment) and critical rail rolling stock will be evacuated to host areas; spare parts will be stockpiled in safe locations	• Continue to operate all major fuel wholesale operations, primary & secondary fuel storage terminals, & other distribution facilities for critical commodities. • Augment vehicle fleet & driver pool for transportation of critical goods as required, following guidelines & procedures established by NDTA for obtaining personnel & equipment from less critical sectors. • Increase vehicle & driver productivity by taking advantage of waived restrictions & weight limitations; minimizing down time; relaxing maintenance requirements; increasing vehicle loads; loading only full pallet quantities; & shipping only necessary commodities. Relocate specialized motor vehicles, critical rolling stock and repair equipment to host areas.	• Continue all warehousing & distribution activities for critical goods, expanding operations where possible through use of commandeered space, worker overtime, & relocated workers. Augment transportation fleet & driver pool as required, following guidelines and procedures established by NDTA for obtaining personnel & new equipment from other sectors. Increase vehicle & driver productivity by taking advantage of waived driver restrictions & weight limitations; minimizing down time; relaxing maintenance requirements; increasing vehicle loads; loading only full pallet quantities; & shipping only necessary commodities. • Stockpile vehicle parts and maintenance manuals.
ROAD NETWORK UTILIZATION	• Advance planning should identify bottlenecks & use all available roads to maximize outbound flow. Effects of congestion on road capacity should be explicitly considered, & contingency plans should be developed to bypass congested bottlenecks. • Traffic flow should be monitored throughout relocation period, preferably by helicopter. • Police & emergency rescue vehicles should patrol evacuation routes to remove disabled vehicles.	• All available means should be employed to persuade population to limit number of vehicles used in evacuation & spread departures evenly over three-day relocation period. • Frequent reports on traffic conditions should be provided throughout the relocation period to allow departing evacuees to enter traffic flow streams at optimal times & to permit motorists to adjust travel plans en route. • Where the possibility of congestion is high, license plate controls should be used to schedule departures. • Move rail panels to host area on flatcars.	• Reception stations should remain open around the clock to facilitate spreading of risk area departure times. • Service stations & rest areas will serve as staging points for emergency vehicle patrols during relocation. • Identify key host area terminals (truckstops and railyards) in advance and plan for their support.
FUEL CONTROL AND DISTRIBUTION	• If fuel shortages do not exist prior to relocation, they are not likely to occur during or after relocation. However, rationing & other point-of-purchase controls may be desirable to conserve fuel against the shortages that can be expected if an attack ensues. • The flow of motor fuel will be redirected from risk area terminals & stations to host area bulk terminals & gas stations. • Intercompany fuel transfers should be permitted to facilitate the redirection of flow from risk to host areas. • To the extent possible, vehicles moving between risk & host areas with critical workers & commodities should refuel in the risk area. • Restrictions on the use of leaded fuel should be eliminated. • Excess fuel produced during relocation period should be stockpiled in host areas.	• Secondary bulk terminals and pipeline outlets will continue to operate to supply host area stations & terminals & critical risk area stations. Once the relocation order is given, only a limited number of critical stations will be resupplied. Where possible, risk area pipeline outlets should supply these stations. • All gasoline stations should remain open around the clock during three-day relocation period until their tanks are drained. Following relocation, only critical stations will remain open. • Non-critical stations with fuel remaining following relocation should deposit keys with public safety officials so that inventories can be used to support movement of critical workers & commodities. • Stations should observe rationing controls & odd/even regulations established nationally during pre-crisis period & evacuation period. • Strengthen critical pipeline terminals and refineries on fringes of target area against attack.	• Supplies to stations along evacuation routes will be bolstered. These stations should remain open around the clock during relocation. • Where appropriate, host area pipeline terminals should be used to advantage in diverting flow of motor fuel. • Following relocation, deliveries to bulk terminals & gasoline stations will be stepped up to meet relocated demand & to develop fuel stockpiles in less vulnerable locales. • Stations should observe rationing controls, odd/even regulations, & any purchase restrictions established nationally before & after relocation. • Construct expedient fuel storage facilities where necessary.

1. INTRODUCTION

1.1 BACKGROUND

The all-hazard, all-contingency civil preparedness program now under study by the Defense Civil Preparedness Agency (DCPA) recognizes two basic strategies for protecting populations threatened by major hazards:

> One is to provide the best protection possible with the population essentially in place, at or near their homes, schools, and places of work. The second is for people to leave the threatened area if time allows (Reference 23).

While the strategy of protection in place remains the primary strategy for defense under nuclear attack conditions, the all-hazard, all-contingency civil preparedness program recognizes the need to plan for the contingency of relocating the population from high-risk areas during periods of severe international crisis. Four primary arguments support the need to plan for crisis relocation:

- It is probable that a nuclear attack upon the United States will be preceded by a crisis build-up of sufficient duration to permit population relocation from high-risk areas.

- If an adversary's cities were to be evacuated during a period of crisis, U.S. cities should also be evacuated.
- It is likely that many citizens will leave large cities in the face of crisis in a "spontaneous evacuation," whether or not they are advised to do so.

- Crisis relocation has been proven feasible in recent large-scale evacuations in the face of hurricane warnings.

The movement of large masses of population in advance of a threatened attack will severely test national and local transportation resources. Plans for evacuating populations, maintaining essential governmental and private services, and transporting critical workers all hinge upon the availability, maintenance, and control of the nation's fuel resources, transportation fleet, and road and rail networks. Past research undertaken by SYSTAN has assessed the transportation requirements accompanying crisis relocation; identified existing levels of vehicle availability, roadway capacity, and fuel supply in the nation's transportation system; identified potential bottlenecks resulting from an inability of the system inventory to support CRP requirements; investigated methods of upgrading system performance under conditions of crisis relocation; and developed guidelines for providing transportation support for the crisis relocation strategy.

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The current study extends the previous research by (1) investigating the effects of a nuclear attack on the reconfigured transportation system and the relocated population, (2) identifying and evaluating alternative means of providing transportation system support following such an attack, and (3) reviewing existing relocation guidance in the light of probable postattack consequences. This research evaluates the problem of providing transportation system support following a nuclear attack, and systematically proposes and evaluates alternative solutions to this problem. Where applicable, the proposed solutions are examined in detail in a case study of Colorado Springs, Colorado.

1.2 OBJECTIVES AND APPROACH

The objectives of this research under Contract No. DCPA01-76-C-0317, as modified, are:

> "...to conduct an analysis and evaluation of previously-completed postattack transportation studies for their relevance to the impact on CRP. Since the disposition of transportation equipment will be affected by crisis relocation, changes from previous studies in the postattack state of the transportation system will be noted and analyzed. In addition to the foregoing, it will determine the readjustments likely to be made in CRP, and their impact on the transportation system, resulting from an extended (i.e., greater than two weeks) crisis relocation. An evaluation of readjustments with potentially large transportation impacts will include, but not be limited to, an increase in the number of critical industries and commuting workers, and the restarting of some non-critical activities by diverting them from risk to host areas. The method of approach shall be composed of the following seven tasks:
>
> Task Number
>
> 1. Prepare Work Plan
> 2. Analyze the Postattack Situation
>   (a) Review Existing Postattack Studies
>   (b) Assess Local and Regional System Damage
>   (c) Quantify Transportation Requirements
>   (d) Identify and Evaluate Postattack Alternatives
> 3. Analyze Extended Crisis Situation
> 4. Analyze Post-Crisis Return
>   (a) Based on the results of the above tasks, develop (1) a comprehensive, consolidated inventory of U.S. truckstop locations and their facilities, and (2) an assessment of their potential roles in crisis relocation.
> 5. Formulate Guidelines
> 6. Develop Prototype Plans
>   (a) Field test prototype plans including truckstop utilization approaches developed in Task 4a above.
> 7. Prepare Final Report"

The general objectives of the research and the Task 2 analyses of the postattack situation are described in Chapters 2, 3 and 4 of Volume I. The Work Plan (Task 1) was developed and reviewed separately, and is summarized in Chapter 1 of Volume I. The analyses of the extended crisis situation (Task 3) and the post-crisis return (Task 4) are reported in Chapters 5 and 6 of Volume I. The inventory of truckstops and their potential roles (Task 4a) is the subject of Volume III. Volume II contains the planning guidelines formulated as part of Task 5, while Volume IV contains the prototype plans developed in Task 6. The field-testing of prototype plans and guidelines (Task 6a) is the subject of Chapter 7 of Volume I. The indicated four volumes are the final report (Task 7) of the contract statement of work.

1.3 SCOPE

Local transportation impacts have been addressed through a detailed investigation of the study area of Colorado Springs. All elements of the Colorado transportation system have been investigated, including network capacities, fuel supplies and sources, and vehicle inventories. The detailed investigation of the Colorado Springs area was further extended to include all critical supply lines entering and leaving the study area during the crisis relocation and postattack periods. Thus, fuel supplies for Colorado Springs were traced to their regional or national sources, and the problems of keeping the fuel supply lines open following an attack were investigated.

As part of the investigation of potential postattack transportation bottlenecks, postattack damage assessments were undertaken for the region comprising the Colorado Springs study area and for critical sources supplying that area. However, no elaborate nationwide damage assessments were undertaken; rather, the study relied on published results of current and past nationwide investigations of nuclear attack effects. To the extent that local requirements and resource availability are affected by nationwide shortages, then, the current study is entirely dependent upon the results of other research efforts.

1.4 A CONSIDERATION OF PAST RESEARCH IN EMERGENCY TRANSPORTATION

Past investigations into the problem of providing emergency transportation in the face of nuclear attack can be divided into two distinct bodies of research. In recent years, SYSTAN and other investigators have investigated alternative strategies for transporting people and critical commodities from areas of high risk in anticipation of a nuclear attack (References 6, 27 and 28). This work has focused almost entirely on the preattack impacts of the crisis relocation strategy. Prior to the current study, little work had been done to assess the postattack implications of the crisis relocation strategy on transportation systems.

Another body of research, undertaken primarily at Stanford Research Institute (SRI) in the mid-1960's, investigated the effects of nuclear attack on various components of the national transportation network under an in-place protection strategy (References 7, 11 and 14). This work focused primarily on the relative vulnerability of each component of the network, but did not anticipate the significant alterations in the location and vulnerability of those components that would accompany a massive evacuation strategy.

1.4.1 Crisis Relocation Planning and the Transportation Network

Recent research of SYSTAN on the Impacts of the Crisis Relocation Strategy on Transportation Systems (Reference 6) has focused on the three principal components of the transportation system: vehicles; networks; and fuel. The current status of the system in the light of each of these components has been surveyed, crisis relocation requirements have been estimated, potential bottlenecks have been identified, and alternative courses of preattack action have been proposed and evaluated. The findings of these investigations are summarized below in Exhibit 1.1:

EXHIBIT 1.1

SUMMARY OF FINDINGS: IMPACTS OF CRISIS RELOCATION STRATEGY ON TRANSPORTATION SYSTEMS

Element	Situation Summary	Key Actions Needed
Vehicles	Availability far exceeds demand in most areas of United States.	Organization and deployment
Road capacity	Local bottlenecks anticipated in most areas; severe problems in northeastern U.S.	Preliminary planning and scheduling along with continuous monitoring and broadcasting of traffic conditions.
Fuel	Demand during and after relocation is less than normal demand.	Redirection of flow from risk to host areas.

Past studies have identified no potential transportation problems severe enough to render a crisis relocation strategy unworkable. The nationwide availability of vehicles far exceeds the anticipated demand, so that the chief limitations to the effective use of these vehicles are likely to be administrative problems of organization and deployment. The capability of local road networks will be stretched, particularly on

the first day of relocation, but careful planning and scheduling coupled with the continuous monitoring and broadcasting of traffic conditions should enable these networks to handle the load in most U.S. cities.

Since the demand for motor fuel during and after relocation is not likely to exceed normal demand, the chief fuel problem will be one of redirecting the flow of gasoline from risk areas to host areas, so that supplies are available where they are needed and reserves may be built up in relatively invulnerable locations.

These findings assume that all cities of 50,000 and over will be evacuated and that all cities of less than 50,000 will serve as host communities. Changes in these assumptions would affect the transport distances involved and require additional research.

1.4.2 Past Postattack Research

Past research into the problems of providing transportation system support during the postattack period has focused almost exclusively on the existing transportation system, assuming in-place protection rather than a crisis relocation strategy. Over a period of years in the mid-to-late 1960's, SRI carried out a program of investigation into all phases of postattack transportation requirements. The SRI investigation estimated surviving inventories of equipment and supplies, personnel, transport networks, fuel and other inputs on a nationwide basis for the major transport modes. While damage to rail and highway transport systems resulting from an attack would be considerable, SRI researchers (References 7, 8, 11) concluded that "the surviving aggregate inventories of such items as motor trucks, locomotives, railroad classification yards, and experienced workers appeared to be more than adequate for deliveries of food and other essentials" (Reference 8). These researchers indicated, however, that the survivability of the transportation system components varied considerably.

1.4.2.1 Vehicles.

In reviewing the earlier studies, Hamberg (Reference 5) has indicated that approximately 50% of the freight-cars and locomotives and 35% of railway passenger-cars were estimated to survive on a national basis. About 64% of the trucks were estimated to remain operational. Data for automobiles were not available.

1.4.2.2 Roads and Railroads.

Earlier researchers have concluded that damage to roads on a national basis is not expected to be so great as to substantially reduce motor transport operations, indicating that detours could usually be

made to avoid damaged road sections. There may be substantial damage to bridges, however. It is expected that between 35% and 55% of the railroad would remain undamaged. According to the referenced studies, the specific percentage of preattack facilities inventory expected to survive is: classification yards, 41%; switching, 37%; and railroad repair shops, 53%.

Hamberg points out, however, that these transportation component survival rates do not take into account the early effects of fallout. "....These effects would in most cases substantially reduce the capabilities during the first and second week after the attack, but on the whole, one could infer that transportation systems are likely to survive fairly well. This conclusion might be dangerously incorrect for two reasons; first, the attacks considered did not target specifically any parts of the transport system and, second, the aggregated results do not reflect what happened at critical points within the system" (Reference 5). At the national level, previous studies (References 7 and 11) have determined that, for the range of attacks studied, major rail and highway links were cut in every major city targeted. In most cases, however, it was found that alternative detour routes existed around the breaks.

In general, it was concluded that cities which sustain relatively heavy damage to rail facilities could expect to undergo critical curtailment of rail service in the immediate postattack period while the surviving aggregate inventories of locomotives, classification yards, and train crews are fitted back together into an operating system. In summary, earlier researchers concluded that, due to their greater flexibility, motor trucks can more readily meet immediate postattack requirements than rail transport.

A significant factor identified in past transportation studies is the need for adequate preattack planning and postattack management of the nation's transportation resources. The capabilities of each of the systems studied are very sensitive to the manner in which equipment is managed in time of stress. Under emergency conditions, decisions regarding transportation priorities, detour routings, and intermodal transfers will be critical, and the need for detailed advance planning is of primary importance (Reference 8).

1.4.2.3 Fuel.

Previous research indicates that between 50% and 80% of the U.S. crude refining capacity would be destroyed by a nuclear attack (References 16, 24, 25 and 26). The petroleum industry is a highly interrelated system, and extremely vulnerable to attack.

Repair of the damaged petroleum supply system will probably be slow. The dependence of petroleum supply on such system components as port terminals, pipelines, railcars, and refineries becomes a liability in time of nuclear attack. Damage to even one segment will delay

recovery of the entire system. Stephens (Reference 16) points out that only a few weapons can reduce refining capability to a critical point, and recovery of operation will be slow due to a shortage of skilled labor, heavy equipment and materials. Nevertheless, it is clear that top priority should be given to repair of this critical industry.

In the event of a nuclear attack, regional imbalance could also be a major problem. If a major production region (for example, Louisiana) were damaged extensively, the amount of crude oil, natural gas, and petroleum products supplied to the northern and Atlantic Coastal states would be critically reduced or cut off entirely.

Another related problem pinpointed by earlier studies is the limited storage capacity available. Few if any areas of the country can sustain themselves if major crude oil supplies are interrupted, or if product supply or delivery is slowed or stopped. For example, a refinery can operate only if feedstock is supplied and if product movement out of the plant takes place, as on-site storage is limited.

1.4.2.4 Summary of Previous Postattack Research.

Earlier studies of transportation system vulnerability under a strategy of in-place protection have indicated that the surviving aggregate inventories of critical transportation equipment, roadways, classification centers, and personnel will be more than adequate for the delivery of food and other essential goods and services. The greater flexibility of trucks suggests that truck transport might be effectively substituted for rail transport during the immediate postattack period. It was determined that adequate preattack planning and management are critical to the successful employment of surviving transportation resources in the immediate postattack period. Earlier studies indicate that damage to the U.S. fuel supply system would be relatively heavy, with the refinery as the most vulnerable element. However, the petroleum industry is a highly-interrelated system, and damage to any one segment could critically affect the others. This contributes to relatively long repair times. While a pipeline could be operational within a few weeks, a refinery may require a year or more to repair depending upon the type and extent of damage and the availability of resources. In the event of a nuclear attack, regional fuel imbalance could be a serious problem. Another related problem pinpointed by earlier research is the limited storage capacity available for stockpiling fuel in most regions of the country.

1.4.3 Implications of Previous Research

A review of past postattack research in the light of the projected effects of a crisis relocation strategy on the transportation network indicates that, while certain potential postattack problems may be alleviated by a relocation strategy, other problems will be intensified.

The extensive vehicle movement and fuel stockpiling accompanying the relocation strategy will render both of these elements less vulnerable to nuclear attack. However, the survival of additional people in areas removed from traditional distribution centers can be expected to intensify the stress imposed on the damaged transportation system. Although the relocation itself will have no impact on the vulnerability of such fixed elements as the road network or fuel refineries, demands on these elements in the postattack period will be greatly affected by the relocation strategy. Damaged roadways will increase the transportation distances covered in providing critical supplies and this additional distance, coupled with the survival of additional population, will create increased demands on surviving fuel refineries.

1.5 OVERVIEW OF THE COLORADO SPRINGS STUDY AREA

By agreement between the Colorado Division of Military Affairs and the U.S. Defense Civil Preparedness Agency, the urbanized area of Colorado Springs has been designated as a target risk area in the event of a nuclear attack threat. This area has been selected for detailed study in the current research effort. The specific area designated to be at risk includes the urbanized area itself and the portion of El Paso County directly south of the urbanized area, including Cheyenne Mountain and the Fort Carson Military Reservation. Those portions of El Paso County north, east and west of the city limits -- including the U.S. Air Force Academy and the Pikes Peak, Monument and Elmore areas -- are judged to be at no risk.

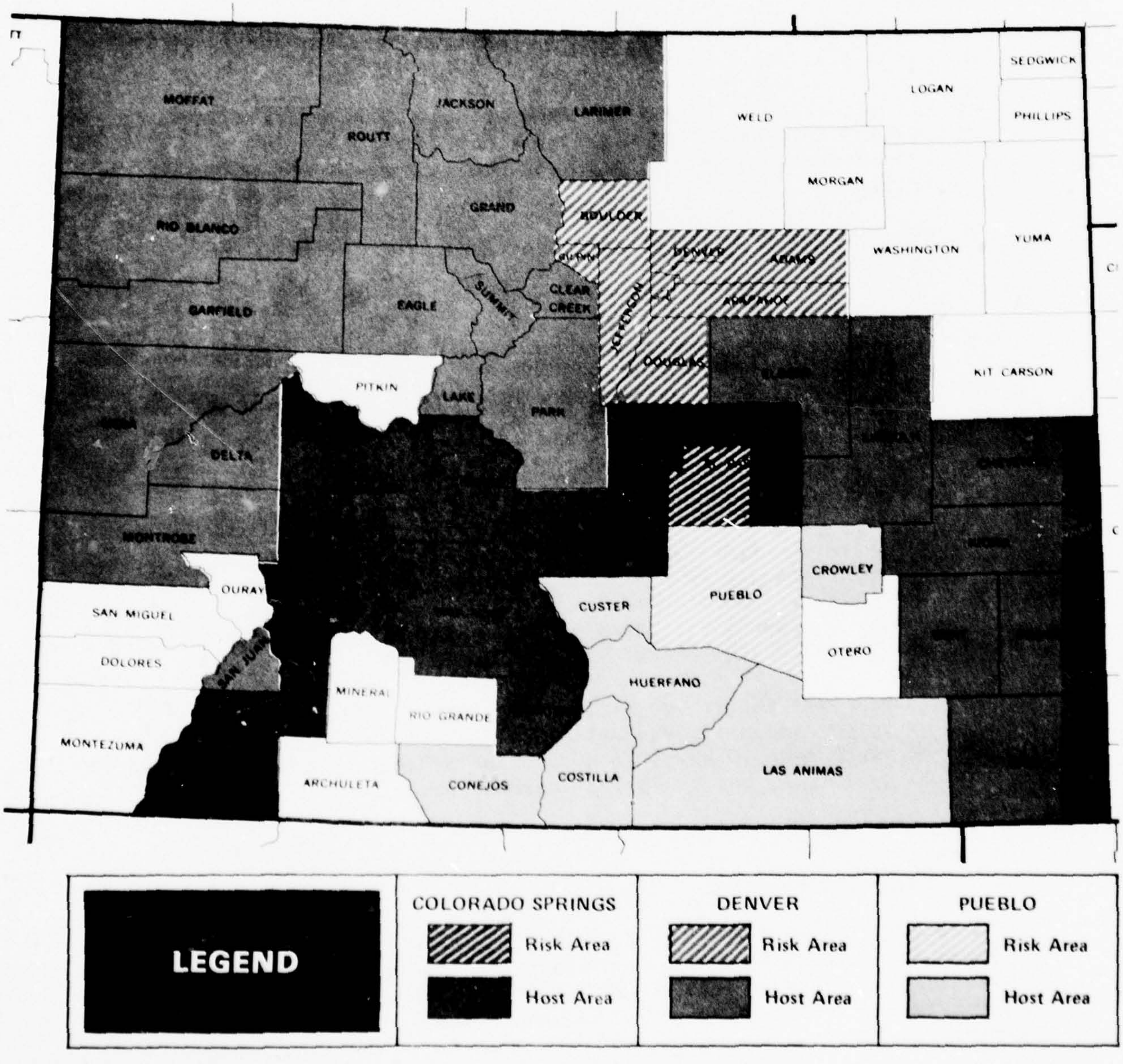
1.5.1 Evacuation Patterns

In conjunction with local officials, DCPA representatives have identified lower-risk areas in surrounding counties to which residents of the Colorado Springs area might be evacuated under threat of nuclear attack. Surrounding counties designated as host counties for Colorado Springs include Alamosa, Chaffee, Fremont, Gunnison, La Plata, Saguache and Teller. In addition, some rural areas of El Paso County will be available for hosting evacuees. The location of the Colorado Springs risk and host areas is mapped in Exhibit 1.2, which also identifies the resident population and the number of evacuees assigned to each host county.

In addition to the Colorado Springs area, the Denver and Pueblo areas are also scheduled for crisis relocation in the event of a nuclear threat. Host counties for residents evacuated from these population centers are also shown in Exhibit 1.2.

EXHIBIT 1.2

Colorado Risk and Host Areas



1.5.2 Key Assumptions

Several of the key assumptions made in developing a crisis relocation plan for Colorado Springs are listed below. These assumptions have been condensed from a longer list of premises appearing in a preliminary crisis relocation plan developed for the Colorado Springs area (Reference 20). Readers desiring more information on the assumptions underlying the crisis relocation, or the specific details of the Colorado Springs evacuation plan, are referred to this document.

1. Relocation of the risk-area population will occur only at the direction of the Governor of Colorado, generally at the request of the President of the United States. Measures preparatory to such relocation may be undertaken during a crisis at local option.

2. Crisis relocation of the risk-area population, when directed by the Governor of Colorado, will be mandatory -- not voluntary -- and in general accordance with the crisis relocation plan.

3. All of the risk-area population, less active-duty military personnel, will relocate to designated host counties or designated parts of El Paso County.

4. After relocation is accomplished, there will be no requirement for goods or services anywhere in the risk area during the relocation period, except as necessary for the preservation of property and the support of essential activities.

5. Some portion of the risk-area population, estimated at between 10 and 20 percent, can be expected to leave the area in advance of a directed crisis relocation. These spontaneous evacuees are expected to consist mainly of families whose members do not have public or emergency responsibilities and who have a vacation home or relatives in mind as a destination. The location, identification, and destination of this group will not be known.

6. Once crisis relocation of the risk-area population has been directed, the minimum duration of the relocation period will be seven days. The maximum duration of the relocation period is uncertain, but could last several weeks.

1.6 REPORT ORGANIZATION

To assess the impacts of a nuclear attack on the reconfigured transportation network under a crisis relocation strategy, the current investigation has developed a quantitative picture of the vehicles, roadways, and fuel situation in the sample study area of Colorado Springs, Colorado. Chapter 2 analyzes vehicle inventories, require-

ments, and alternatives at the national and local level and discusses the implications of this analysis on crisis relocation planning guidelines. Chapter 3 assesses probable damage to the road and rail networks and evaluates alternative routing patterns along with attendant increases in distance and travel times. The potential role of truckstops under crisis relocation conditions is also analyzed. Chapter 4 traces the fuel supply system, discusses the fuel needs of evacuees, assesses probable damage to the fuel supply and distribution system, and evaluates various alternative courses of action, including stockpiling, changes in distribution procedures, and conservation measures. Chapter 5 analyzes the extended crisis situation, in which the initial crisis relocation is not followed by an attack or a cessation of hostilities and risk area residents reside for relatively long periods of time in the host area. Chapter 6 summarizes promising strategies for postattack transportation system support and discusses the implications of these strategies on crisis relocation planning activities. Chapter 7 summarizes the results of interviews with planners and industry personnel designed to validate the planning guidance and materials produced as a result of this case study and past transportation problems under crisis relocation conditions.

2. VEHICLE INVENTORIES, REQUIREMENTS AND ALTERNATIVES

This section discusses the normal and postattack availability of vehicles for passenger and cargo movement throughout the United States and in Colorado Springs in particular. Vehicle inventories are measured against the requirements imposed by the postattack situation, and alternatives for improving the emergency utilization of private and public vehicles are identified and evaluated. The conclusions presented reflect the results obtained from: (1) previous studies; (2) extensive discussions with representatives of the rail and trucking industries, various trade associations, and public transportation planners; (3) damage assessment; and (4) an analysis of postattack transportation requirements and vehicle availability. The related subjects of roads and fuel are discussed in subsequent subsections.

2.1 DISPOSITION OF VEHICLES UNDER A CRP STRATEGY

The major vehicle requirements imposed by a crisis relocation strategy have been analyzed in an earlier SYSTAN study (Reference 6). This study concluded that the United States appears to have vehicles in abundance to support a crisis relocation strategy. At least 80% of all evacuees will relocate in private automobiles. If these evacuees rely on the "first" automobile available to each household, a large store of "second" automobiles will be left in reserve within the risk area. In the typical city, the supply of local buses (including schoolbuses, tour buses, and urban transit vehicles) will be adequate to support the relocation of autoless evacuees. This will not be the case in all cities, particularly in those large eastern cities with a high proportion of autoless residents. Planners in these cities will have to supplement the local bus fleet with intercity buses, rail passenger service and, as a last resort, trucks and freight-cars.

Sufficient vehicles are also available to provide essential supplies to the relocated population. A conservative estimate of the number of non-essential goods commonly transported reveals that these goods tie up 40% of the vehicles used in intercity transportation and half the trucks used in local transportation. Thus, the inventory of vehicles and drivers available for transporting critical commodities could be substantially increased under crisis relocation conditions. The distance covered by local supply vehicles will be increased by the relocation strategy, but the local vehicle inventories appear to be more than equal to this additional stress, and several measures have been identified for improving vehicle productivity under crisis conditions.

Under crisis relocation conditions, the chief problem with transportation equipment is much more likely to be one of organization than of vehicle shortages. Although vehicles for relocation and supply exist in abundance, they are not always in the right place and may be subject to conflicting pressures under emergency conditions. At the national

level, advance planning should be undertaken to ensure that the intercity bus fleet is directed to those cities most in need of relocation assistance. At the state and local levels, clear chains of command need to be drawn up and publicized. NDTA members cite instances in past emergencies in which conflicting claims were made on emergency equipment, and police cordons failed to admit properly authorized individuals attempting to salvage transportation equipment in the face of an oncoming flood.

2.2 OVERVIEW OF NATIONAL AND LOCAL VEHICLE INVENTORIES

In order to determine the postattack availability of vehicles following a nuclear attack, it is first necessary to trace the location and use of the nation's vehicle fleet under normal conditions. As a basis for assessing postattack availability, vehicle inventories and usage patterns were assembled for the nation as a whole and for Colorado Springs in particular. The impact of a crisis relocation strategy on vehicle location and use was then documented prior to undertaking an assessment of the vulnerability of the vehicle fleet to a nuclear attack.

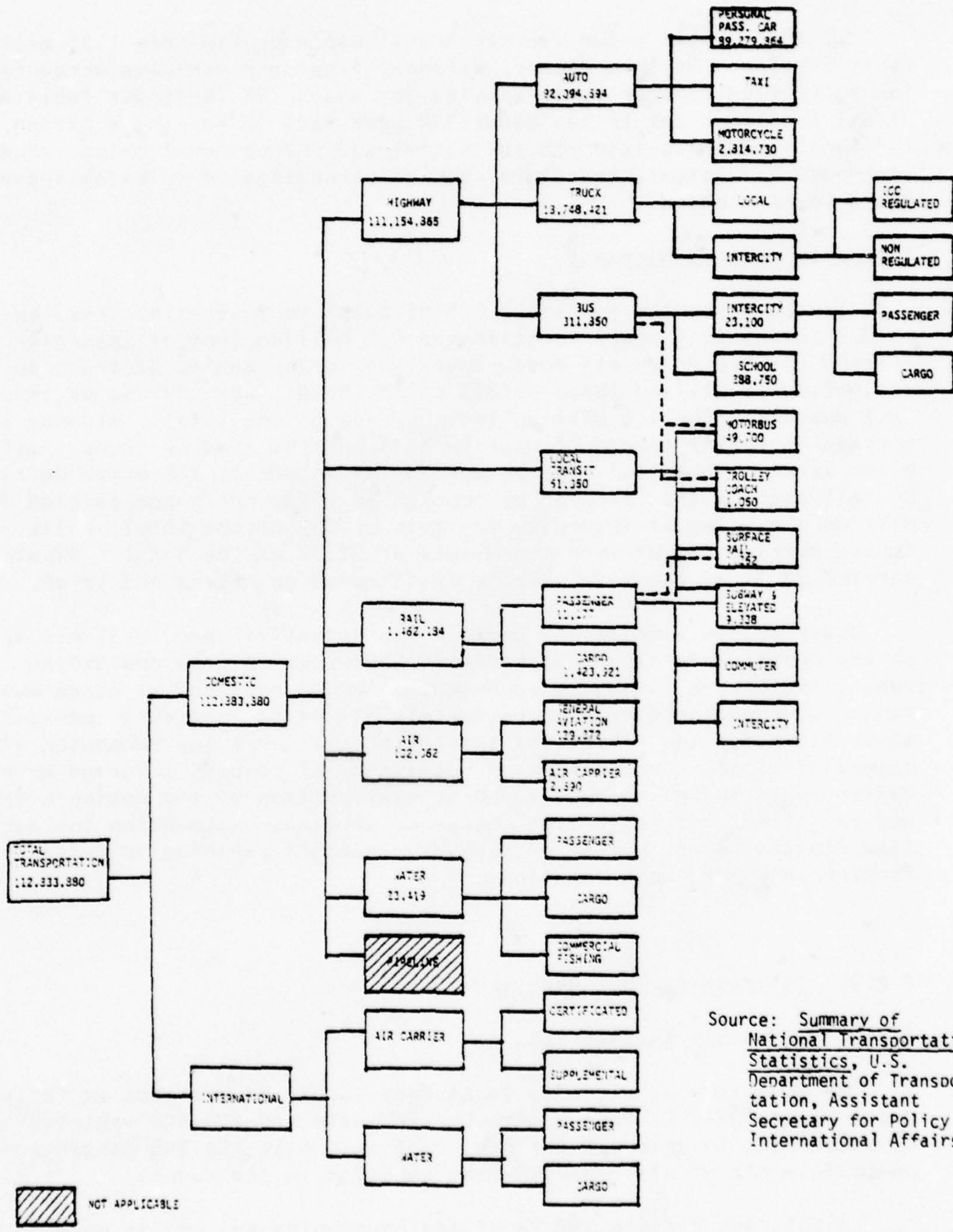
2.2.1 Nationwide Overview

2.2.1.1 Vehicle Inventories.

In 1970, there were approximately 111.2 million highway vehicles registered in the United States (Exhibit 2.1). Automobiles accounted for 92.1 million of this number, or about 83% of the total. Public transit vehicles numbered 384,377 in 1970, with buses accounting for 81% of total public transit vehicles. Schoolbuses constituted 93% of the bus group. Truck registrations in the United States as of 1970 numbered approximately 18,748,000, of which about 95% were private and commercial vehicles and 5% percent were public vehicles. Of the total number of trucks in the nation, approximately 97% were single units with two or three axles, and 3% were tractor-trailer combinations with three or more axles.

EXHIBIT 2.1

NUMBER OF VEHICLES, 1970



Source: Summary of National Transportation Statistics, U.S. Department of Transportation, Assistant Secretary for Policy & International Affairs.

2.2.1.2 National Usage Patterns.

Automobiles

In 1973, total motor vehicle travel was approximately 1.31 million vehicle-miles. Of this number, personal passenger vehicles accounted for about 1.04 million vehicle-miles, or about 79% (Appendix Table A-3). Of all passenger car trips, about 37% were made in earning a living, 31% for family business, and 22% for social and recreational trips. Under emergency conditions, therefore, a high percentage of existing travel could be eliminated.

Intercity Freight Movement

Trucks accounted for about 20% of total vehicle-miles traveled in 1973. During that year, an estimated 5.5 billion tons of intercity freight was hauled by all modes operating in the United States. An estimated 1.9 billion tons, or 37% of the total, was carried by truck. Rail accounted for 1.6 billion tons, or 30% of the total. Because the average intercity length of haul by rail exceeds that by truck (531 miles versus 276 miles), the percentage of intercity ton-miles carried by rail exceeds that carried by truck. In 1973, railroads carried 858 billion ton-miles of intercity freight, or 39% of the total, while trucks carried 505 billion ton-miles, or 22.6% of the total. Pipelines carried 22.7% of the total, while 16.0% moved on rivers and lakes.

Under crisis conditions, certain non-essential cargo will not move on the normal intercity transportation network. A previous SYSTAN report (Reference 6) separated essential and non-essential cargo movements, and concluded that approximately 62% of the nation's intercity truck ton-miles and 41% of the intercity rail ton-miles consisted of essential cargo. Curtailment of non-essential shipments during an evacuation would therefore free a substantial portion of the nation's truck and rail fleet for performing emergency services, augmenting the local flow of critical supplies, or providing support vehicles in relatively invulnerable host-area locations.

2.2.2 Colorado Springs Overview

2.2.2.1 Vehicle Inventories.

An inventory of vehicles in El Paso County is provided in Table 2.1. As of 1974, El Paso County had an estimated 200,000 vehicles, most of which were in Colorado Springs. The estimated 150,295 passenger cars constitute 81% of all over-the-road vehicles in the county.

In Colorado Springs, 92.8% of the households own one or more automobiles and 44.5% own two or more. These percentages are significantly higher than those for the nation as a whole. In the U.S., 79.5% of all households own one or more automobiles (see Exhibit 2.2).

TABLE 2.1

VEHICLE INVENTORY IN EL PASO COUNTY, 1974

Passenger Cars		150,295
Buses		
Intercity Bus	9	
Local Bus	31	
School Bus	174	
Tour Bus	6	
Van	8	
Limousine	3	
Total Buses		231
Cargo Vehicles		
Trucks		
Pick-ups	31,429	
Dump Trucks	1,815	
Farm Trucks	1,172	
Metropolitan Trucks	360	
Total Trucks	34,776	
Tractor Units	508	
Trailers	14,404 *	
Total Cargo Vehicles		49,688
Recreational Vehicles		87
TOTAL VEHICLES		200,301

*Includes trailers of all types and sizes.

Source: Registrar, County of El Paso, Colorado.

EXHIBIT 2.2

AUTO OWNERSHIP

IN

U.S. and COLORADO SPRINGS

	PERCENT OF HOUSEHOLD OWNING				
	No Car	One or More Cars	One Car	Two Cars	Three or More Cars
ALL US HOUSEHOLDS........	20.5%	79.5%	49.3%	24.6%	5.6%
ALL COLORADO SPRINGS HOUSEHOLDS............	7.2%	92.8%	48.3%	36.3%	8.2%

Source: 1. 1973/74 Automobile Facts and Figures, Motor Vehicle Manufacturers Association of the United States, Inc., Detroit, Michigan.

2. 1970 U.S. Census of Housing: Housing Characteristics for States, Cities and Counties. Volume I, Part 7, Colorado, U.S. Bureau of the Census, Washington, D.C.; pp. 7-122 and 7-79.

Transit vehicles in Colorado Springs number approximately 275, including 44 taxicabs. Schoolbuses account for the largest share of this total. The number of transit vehicles in Colorado Springs by type and seating capacity is listed in Appendix Table A-1.

It is estimated that there were 34,776 trucks in El Paso County in 1974, of which 31,429 (90%) were pick-ups. The remaining 10% include dump trucks, farm trucks and metropolitan trucks. In addition, there were 508 tractor units and a total of 14,404 trailers, of which an estimated 1,000 were heavy combination units. These figures include both privately-owned vehicles and those owned by the County's 27 motor freight public carriers. The number of common carrier cargo vehicles in Colorado Springs by weight is listed in Appendix Table A-2.

2.2.2.2 Automobile Usage Patterns.

Passenger car use in Colorado Springs and the United States as a whole exhibits similar patterns. The table below shows that travel to and from work accounts for between one-quarter and one-third of the total passenger car trips:

PASSENGER CAR USE IN COLORADO SPRINGS
AND THE UNITED STATES

Purpose of Travel	Colorado Springs	United States
Earning a Living	42.0%	42.1%
Social and recreational	34.0	33.4
(visit friends or relatives)	(12.0)	(12.2)
Family business	19.4	19.6
Educational, civic, religious	4.7	5.0
Total	100.0%	100.0%

(Sources: Transportation Plan Summary Report (Second Draft), Pikes Peak Area Council of Governments and the Colorado Division of Highways in cooperation with the U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., 1974, page 64; and Nationwide Personal Transportation Study, Household Travel in the U.S., Report No. 7, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., 1972, page 4).

Colorado Springs and U.S. automobile occupancy rates are also similar. The Colorado Springs survey cited above indicated an average automobile occupancy rate of 1.7 persons per trip, while the U.S. average was 1.9 (Reference 1).

The majority of trips (54.1%) on a national level are under five miles in length (see Exhibit 2.3). These trips account for slightly over 11% of the vehicle-miles traveled. Statistics for average trip length in Colorado Springs are unavailable for comparison.

2.2.2.3 Public Transit Service.

The City Bus Service provides public transit service within Colorado Springs along ten routes, all converging at a common off-street transfer point within the CBD. Present transit ridership is roughly 2,000 passengers per day, which accounts for less than 1% of total trip-making in the Colorado Springs area. Intercity bus service is provided by Continental Trailways and Greyhound. Both companies maintain terminals in the CBD, within one block of the transfer point for local transit service. Buses stopping at Colorado Springs travel to and from Denver and Pueblo in Colorado and to El Paso, San Antonio and Dallas in Texas.

2.2.2.4 Local Truck Movement.

Within Colorado Springs, there are four major carriers, six medium-sized companies, and an estimated 30 to 35 small firms. The number of moving and storage firms operating in Colorado Springs is unusually high because of the heavy concentration of transient military personnel. The business is highly seasonal, with heavy activity occurring only during the four summer months. Most of the local "call and demand" carriers have temporary storage facilities.

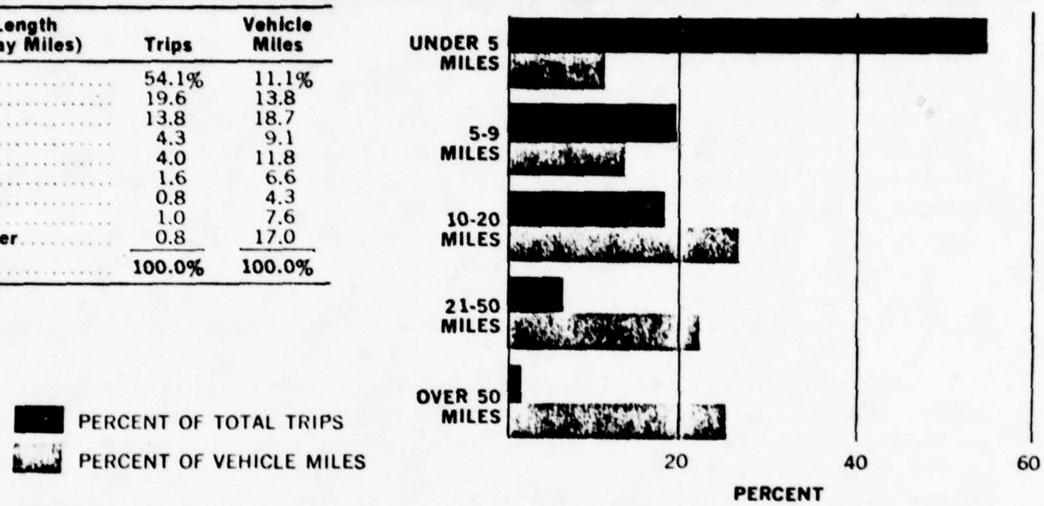
The business of scheduled freight carriers is far more regular than that of call and demand carriers. The largest scheduled carriers (Pacific International Express, Navajo, etc.) serving Colorado Springs function primarily as break-bulk agents, breaking down large shipments into small truckloads for local delivery. Colorado Springs has few outbound shipments relative to the number of inbound shipments, so the trucks of many carriers leave the area empty.

EXHIBIT 2.3

LENGTH OF AUTOMOBILE TRIPS

(NATIONWIDE AVERAGES)

Trip Length (One-Way Miles)	Trips	Vehicle Miles
Under 5	54.1%	11.1%
5-9	19.6	13.8
10-15	13.8	18.7
16-20	4.3	9.1
21-30	4.0	11.8
31-40	1.6	6.6
41-50	0.8	4.3
51-99	1.0	7.6
100 and over	0.8	17.0
Total	100.0%	100.0%



SOURCE: U.S. Department of Transportation, Federal Highway Administration, *Nationwide Personal Transportation Study* (1969), Reports No. 1 and 7.

2.2.3 Local Vehicle Assignments Under Crisis Relocation Conditions.

2.2.3.1 Movement of People Under CRP Conditions

The major transportation demands posed during and after the relocation of the Colorado Springs population have been analyzed in an earlier SYSTAN study (Reference 6). This study concluded that private automobiles (approximately 35,000) would be the primary means of moving relocatees from the risk to the host area. Automobiles would be supplemented by buses and other means of transportation where necessary. The schoolbus fleet, in combination with the existing local bus service, was found to be adequate for moving those residents without access to a private automobile. Once the host area is reached, use of private automobiles would be restricted. Following relocation, risk area buses would provide public transportation within the host area. Buses and carpools would be used to the extent possible in the commuting of critical workers. It appears that there would be a sufficient number of vehicles for the necessary movement of people during and after the crisis relocation period.

2.2.3.2 Movement of Urban Cargo Under CRP Conditions.

Whereas only 62% of current intercity truck movements and 41% of intercity rail movements were designated as essential under crisis relocation conditions, roughly 51% of local urban truck movements were found to be essential (Reference 6). Thus, the movement of essential urban cargo under CRP conditions would require about one-half the number of vehicles used under "normal" conditions. Under crisis relocation conditions, however, the distance traveled by urban vehicles would be increased, introducing some transportation stress. In Colorado, long evacuation distances, coupled with a heavy concentration of manufacturing activity in the Denver area, will cause vehicle mileage requirements for local deliveries to triple under crisis relocation conditions (Reference 6). This tripling of mileage can be met in the short run by a 50% increase in vehicles and a doubling of the available driver supply. These vehicles and drivers will be available locally if the movement of non-essential goods is curtailed and the supply of vehicles and drivers is carefully coordinated.

2.3 DAMAGE ASSESSMENT

Under a crisis relocation strategy, approximately 90% of the U.S. population is assumed to survive a nuclear attack. This figure exceeds the in-place protection strategy survival rate by about 70 million people. Evacuation from the Colorado Springs risk area to adjacent host areas results in an even higher survival rate, postulated at 98% of the population. A damage assessment analysis conducted as part of the current study showed that vehicle survival under crisis relocation

TABLE 2.2

VEHICLE SURVIVAL SUMMARY

Category	Number		Survival Rate (%)		
			In-Place		CRP
	U.S.	Colorado Springs	U.S.	Colorado Springs	Colorado Springs
Motor					
Automobiles	92,100,000	150,295	--	37	63
Buses	311,345	231	--	31	81
Trucks	18,748,000	34,650	52	29	65
Rail					
Freight-Cars	2,009,635	50	39	20	60*
Passenger-Cars	27,800	--	22	--	--
Line-Haul Locomotives	11,900	1	49	0	0
Switching Locomotives	7,998	2	38	50	100

*Assuming 50% of all freight-cars are moved to the host area.

(Sources: References 3 and 4 and SYSTAN analysis.)

conditions also exceeded that experienced under a strategy of in-place protection. Table 2.2 summarizes vehicle survival in the U.S. and Colorado Springs under an attack comparable to the UNCLEX-CHARLIE attack pattern.

2.3.1 Automobiles and Buses

Although several earlier studies have analyzed various aspects of the vulnerability of freight transportation to nuclear attack, relatively little work has been done on the nationwide vulnerability of passenger transportation. For this reason, Table 2.2 lists no nationwide data for the survival of automobiles and buses under a strategy of in-place protection. A few studies, however, have investigated the vulnerability of local transportation systems. One such study (Reference 2) found that damage to automobiles remaining in the urban area was severe, with only 10% undamaged and usable. In this study, it was assumed in the target model that some of the vehicles were inside buildings, some parked at shelters, and others parked outside near residences.

Under a strategy of in-place protection, it has been determined that 37% of the automobiles in the Colorado Springs risk area would survive the postulated nuclear attack. Under a crisis relocation strategy, 63% of the automobiles in Colorado Springs area would be expected to survive. These results were based on using a mean lethal overpressure of 5 psi, and assume destruction of a large number of second household automobiles remaining in the risk area under the latter strategy.

As with automobiles, relatively little study has been done on the postattack accessibility of buses at the national level. In Colorado Springs, damage assessment analysis indicates that, on an in-place basis, bus survival would be 31% for the Colorado Springs risk area. Under CRP, the survival rate would be 81%. As with automobiles, these results were based on a mean lethal overpressure of 5 psi (Reference 2). It is assumed that most buses would be removed from the risk area during the evacuation, but that some would continue to reenter the risk area in transporting critical workers during and after crisis relocation.

2.3.2 Trucks and Railroads

2.3.2.1 U.S. Situation.

Damage assessment for trucks and railroad rolling stock is summarized in Table 2.2 and shown in more detail in Table 2.3. At the national level, the accessibility results are based on the UNCLEX-CHARLIE attack and were developed by the Federal Preparedness Agency (References 3 and 4). The UNCLEX-CHARLIE attack is based on an in-place protection mode. As shown in the tables, approximately 53% of the trucks are available for use at the national level at D+15. Railroad

TABLE 2.3

DAMAGE ASSESSMENT OF TRUCKS AND RAILROAD ROLLING STOCK

AT THE NATIONAL LEVEL (BASED ON UNCLEX-CHARLIE ATTACK)

Category	Preattack Level	Destroyed or Severely Damaged	Accessible for Repair D+180	Accessible for Use		
				D + 1	D + 15	D + 30
TRUCKS						
No. of Petroleum Trucks	48,656	16,188	4,187	18,016	25,192	26,768
% of Preattack Total	100	33.3	8.6	37.0	51.8	55.0
No. of Farm Trucks	2,832,813	204,268	151,279	1,659,387	2,301,750	2,405,150
% of Preattack Total	100	7.2	5.3	58.6	81.3	84.9
No. of All Other Trucks	8,499,576	3,518,421	151,279	2,672,428	3,681,781	3,921,268
% of Preattack Total	100	41.4	9.6	31.4	43.3	46.1
. of Total Trucks	11,381,045	3,738,841	967,775	4,349,827	6,008,716	6,353,181
% of Preattack Total	100	32.9	8.5	38.2	52.8	55.8
RAILROAD ROLLING STOCK						
No. of Freightcars	2,009,635	761,687	322,668	555,679	777,435	839,048
% of Preattack Total	100	37.9	16.1	27.7	38.7	41.8
No. of Passengercars	27,800	16,082	4,005	4,666	6,216	6,872
% of Preattack Total	100	57.8	14.4	16.8	22.4	24.7
No. of Line-Haul Locomotives	11,900	3,411	549	4,040	5,827	6,694
% of Preattack Total	100	28.7	4.6	33.9	49.0	56.3
No. of Switching Locomotives	7,998	3,698	514	1,961	3,003	3,282
% of Preattack Total	100	46.2	6.4	24.5	37.5	41.0

Source: Federal Preparedness Agency, Ready Summary Analysis of Scheduled Availability for Production (SASAP) Attack UNCLEX-CHARLIE Category THI Motor Trucks National Summary and Category TRS Railroad Rolling Stock National Summary, FPA, General Services Administration, Washington, D.C., October 1977.

rolling stock accessibility at D+15 is: freight-cars, 39%; line-haul locomotives, 49%; switching locomotives, 38%. Railroad rolling stock accessibility, however, is considerably less immediately after the attack, ranging from 25% to 34%.

UNCLEX-CHARLIE attack data on damage to railroad classification yards and repair shops is classified and unavailable for this report. Reviewing earlier studies, Hamberg reports a survival rate of 41% and 53% respectively for classification yards and repair shops. In referring to the general range of damage to transport systems, however, Hamberg cautions that "these effects would in most cases substantially reduce the capabilities during the first and second week after the attack, but on the whole, one could infer that transportation systems are likely to survive fairly well. This conclusion might be dangerously incorrect for two reasons: First, the attack considered did not target specifically any parts of the transport system and, second, the aggregated results do not reflect what happened at critical points within the system" (Reference 5).

Previous studies show that, particularly for rail systems, disruption is more serious than indicated by percentage survival of various categories of equipment and fixed facilities.

2.3.2.2 Colorado Situation.

In Colorado Springs, it was assumed that trucks sustaining a blast of 5 psi or more were damaged and not accessible for use. Under a strategy of in-place protection, the survival rate for trucks was 29% for the Colorado Springs risk area. The survival rate for some trucks (e.g., farm trucks), of course, is much higher than for others which are primarily within the City of Colorado Springs (e.g., metropolitan trucks). Under a CRP strategy, with most trucks out of the risk area at the time of the postulated attack, the survival rate is approximately 65%.

Railroad rolling stock survival in Colorado Springs on an in-place basis was 20% for freight-cars and approximately 33% for locomotives. Under CRP conditions, approximately 60% of the freight-cars and two of the three locomotives (line haul and switching) would be accessible, assuming evacuation of this equipment to the host area during relocation (Table 2.2).

Colorado railroad officials indicate that new track around the damaged area could probably be laid and ready for operation approximately one month following an attack.

2.4 POSTATTACK VEHICLE REQUIREMENTS

The estimation of postattack transportation requirements at the national level requires a detailed model of commodity flow before and after the postulated attack. Such a modeling effort was beyond the scope of the current research. Local measurements in the Colorado Springs study area have been inferred for several key commodities. Because of the interrelated nature of the vehicle, fuel and roadway elements of the transportation system, however, it is difficult to divorce the local picture from national considerations. For example, an apparent surplus of surviving fuel in one area of the country may be depleted by demands in other fuel-starved areas. Thus, any attempt to draw precise conclusions is hindered by the lack of a national overview of the postattack transportation situation. However, some general observations may be made on the basis of local studies and the national studies that currently exist.

2.4.1 Movement of People Under Postattack Conditions

During the immediate postattack period, the demand for travel-to-work vehicles will be less than under "normal" conditions, since many of the usual employment locations will have been destroyed. The number of workers at many surviving places of employment, of course, will increase. Personal travel will be restricted throughout the early postattack period in order to conserve fuel. Although precise postattack scenarios for population return to surviving homes, work, etc. have not been developed at the national planning level, available evidence indicates that there will be a sufficient number of vehicles for necessary transport of people during this period. Restrictions on movement are more likely to stem from fuel shortages or damaged roadways than from a shortage of vehicles. These considerations are discussed in subsequent chapters of this report.

2.4.2 Movement of Cargo Under Postattack Conditions

Postattack requirements for goods movement at the national level have not yet been completely defined, although some work has been done in this field (Reference 7). Earlier studies have found, however, that for a range of several different attacks "the surviving aggregate inventories of such items as motor trucks, locomotives, railroad classification yards, and experienced workers appeared to be more than adequate for deliveries of food and other essentials." (Reference 8). The above-referenced studies were based on an assumed in-place protection posture.

Under crisis relocation conditions, the percentage of surviving cargo vehicles would be greater, whereas the destruction of manufacturing industries is similar to that under an in-place protection posture. The requirements of the surviving population would, of course, increase,

as more survivors are expected following a crisis relocation. In the immediate postattack period, debris removal and clean-up operations will create a demand for selected on-the-road and off-the-road vehicles. In the days and months following the attack, as production is gradually restored, the demand for general transportation of manufactured goods will increase. Appraisal of this varying nationwide demand and detailed survey of surviving cargo vehicles is beyond the scope of this study. Available evidence indicates, however, that there will be a sufficient number of cargo vehicles to meet essential requirements.

One overall assessment of the requirement for supply vehicles under crisis relocation conditions estimates that about 2.43 tractor-truck and trailer loads per day are needed to supply 10,000 people (Reference 27). Using this estimate, one vehicle making one round-trip per day between local supply centers and the relocated population could support about 4,100 people per day. In the United States, there is an average of one tractor-truck and trailer combination for every 200 people.

It is estimated that 90% of the U.S. population would survive the postulated attack under a strategy of crisis relocation. The number of surviving trucks under such a strategy is not known nationally. However, under an in-place protection strategy, 52% of the nation's trucks are expected to survive a comparable attack. Taking 52% as a worst-case estimate of truck survival under crisis relocation conditions, the nation would be left with an average of one tractor-trailer combination for every 350 people. (In Colorado, the ratio is expected to be more favorable, at one vehicle per 270 survivors.) Even with the additional distances required, this should be adequate for the movement of essential goods if roadways are available and sufficient fuel survives.

2.5 IDENTIFICATION OF ALTERNATIVES

2.5.1 Automobiles

Available evidence indicates that in the risk and host areas, assuming relocation with 60%-70% automobile accessibility, there will be a sufficient number of vehicles in the postattack period to meet basic population transport requirements. Approximately 90% of host area resident and relocatee families will have automobiles in the postattack period. Moreover, travel in the postattack period will necessarily be severely restricted by fuel supply constraints (see Section 4). Accordingly, severe restrictions will be placed on personal automobile usage, even though the surviving vehicle supply is expected to be more than adequate to meet travel demands.

2.5.2 Trucks and Railroads

One of the most important factors identified by earlier studies is the need for adequate planning, organization and postattack management of transportation resources. The capabilities of each of the transport systems studied are very sensitive to the manner in which equipment is managed in time of stress. During the immediate postattack period, decisions regarding transportation priorities, vehicle routing, and intermodal transfers will be of major importance. In view of this, the value of detailed advance planning and training in the preattack period cannot be overemphasized.

2.5.2.1 Moving Critical Vehicles to the Host Area.

Due to their concentration in railroad classification yards, switch engines will have a lower survival rate than line-haul locomotives and freight-cars. Switch engines will be urgently needed during the postattack period, and plans should therefore be made to move as many as possible out of the risk area during the latter part of the relocation period, without disrupting the orderly flow of necessary work. The location of host area points where critical rolling stock may be moved is discussed in more detail in Chapter 3. Railroad debris removal and track repair equipment should also be moved to the host area. Furthermore, specialized motor vehicles such as ambulances, dump trucks, and debris removal equipment should be moved to the host area during relocation to the extent that this is possible without disrupting risk area operations.

2.5.2.2 Assembling Parts Inventories in Host Area.

Locomotive spare parts and maintenance manuals should be moved to the host area during the crisis relocation period. In addition, parts for trucks and other critical vehicles should be moved to the host area. In Denver and Colorado Springs under "normal" conditions, the inflow of cargo is much heavier than the outflow; therefore, cargo vehicles generally have excess outbound capacity and can readily carry vehicle parts and other critical items.

2.5.2.3 Intermodal Transfer.

The greater flexibility of truck movement in time of emergency suggests that truck movement might be effectively substituted for rail movement during the immediate postattack period. Most commodities could be transferred between rail and truck. For example, the major food items coming into Denver by rail are wheat, other cereal products, and canned goods, usually in palletized form. These items can readily be carried by truck. Possible host area locations for the construction of

makeshift terminals and plans for such terminals should be made part of the transportation annex of local plans. To ensure the most efficient use of fuel and manpower, such substitutions of service would usually be made on hauls of relatively short distance. Furthermore, the railroads should resume their customary role once rail service is reestablished.

2.5.2.4 Easing Transportation Stress.

In addition to moving vehicles and parts to the host areas and substituting trucks for rail transport during the immediate postattack period, certain strategies have been identified for improving driver productivity and vehicle productivity under emergency conditions. These strategies are discussed below.

As part of earlier studies (References 8, 9 and 10), distribution managers for major food wholesalers serving five different metropolitan areas of the U.S. were interviewed at some length regarding potential measures that might be employed to ease the transportation stress imposed on the food distribution system by a crisis relocation. Similar interviews were carried out in the case of motor fuel distributors serving Colorado Springs. Most of the distribution managers interviewed felt that the vehicle mileage covered by their trucks fleets in making local deliveries could be doubled under emergency conditions; additional increases would require additional equipment. The larger food distributors interviewed indicated a willingness to lease additional equipment in time of emergency. This is their current practice when demand surges render their truck fleets inadequate. Many gasoline distributors rely heavily upon public carriers under normal circumstances, and would follow this strategy instinctively during an emergency. Additional strategies for increasing truck and driver productivity include:

1. RELAXING REGULATORY CONSTRAINTS

   a) Relaxing union and DOT driver restrictions

   b) Ignoring over-the-road weight limitations

2. IMPROVING UTILIZATION OF EXISTING EQUIPMENT

   a) Relaxing maintenance requirements

   b) Minimizing downtime

   c) Shipping only full-pallet commodity loads

   d) Eliminating light loads

   e) Shipping only necessary commodities

3. OBTAINING ADDITIONAL EQUIPMENT AND DRIVERS

a) Leasing equipment

b) Using incoming equipment from manufacturers

c) Commandeering additional drivers and equipment from less critical sectors of the economy

Each of these strategies, discussed in detail in Impacts of the Crisis Relocation Strategy on Transportation Systems (Reference 6), is briefly reviewed in the following paragraphs.

(A) Relaxing Regulatory Constraints. Relaxing union and DOT restrictions on the length of time a driver may spend at the wheel during a tour of duty (consistent with safety precautions) would increase driver availability, while waiving truck weight limitations would improve vehicle utilization.

(B) Improving Utilization of Existing Equipment. Existing equipment is not fully utilized, and additional vehicle-hours may be realized over short periods by cutting back on maintenance procedures. By ignoring brand differences and loading only full-pallet loads of specified items, additional savings of from one to three hours per trip may be attained at the warehouse loading dock. Another means of improving vehicle utilization under emergency conditions is to ship only essential items. Every retail grocery store and grocery wholesaler carries many items which would not be required for survival under crisis relocation or postattack conditions. The identification of non-essential items is not simply a matter of separating food and non-food items and shipping only food items to host-area outlets. While some non-food items carried by grocers are clearly not essential to survival (e.g., toys, hair spray, and tobacco products), many other items in this classification will contribute significantly to the well-being of the evacuated population (e.g., aspirin, toilet tissue, and detergents).

(C) Obtaining Additional Drivers and Equipment. One obvious means of coping with the transportation stress imposed on the local food and fuel distribution systems by crisis relocation or postattack conditions is to secure the use of drivers and equipment from other, less critical sectors of the distribution community. This approach is currently practiced on a small scale by most food distributors. On a larger scale, many fuel distributors rely entirely on the services of leased tankcars. Under emergency conditions, additional vehicles and drivers for the movement of food and other critical products might be obtained from the household moving industry and from manufacturing firms shutting down for the duration of the crisis. In addition, back-haul shipping could also be utilized.

Since, as noted above, existing equipment is not used to capacity, it is necessary to estimate the additional usage that may be obtained from this equipment before additional drivers and equipment are necessary. Estimates of the requirements for additional drivers and equip-

ment have been made in earlier studies (References 6 and 9) on crisis relocation, but they apply to the immediate postattack period as well. Table 2.4 lists the estimated range of increases in driver and vehicle productivity associated with each of the labor- and equipment-saving measures proposed in this section.

The possible increase in driver productivity for food trucks is 51%, while the average increase in productivity possible for existing food transportation vehicles is 112.5%. This figure could range from 76% to 149%, depending primarily on existing vehicle downtime. Potential productivity increases are slightly less pronounced for fuel trucks, and depend primarily upon the relative number of trucks currently in service 20 hours per day, as opposed to more common ten- and twelve-hour operating spans. This varies, of course, from company to company.

Exhibit 2.4 charts the rough results of Table 2.4 as a function of various transportation stress factors. On the average, a transportation stress factor of 2.5 for food deliveries (i.e., a 150% increase in vehicle mileage) would require an influx of 18% more vehicles and 71% more drivers from other sectors of the economy. A doubling of local fuel truck mileage (i.e., a transportation stress factor of 2) would require, on the average, an 8% increase in vehicles and a 63% increase in drivers. These estimates do not allow for attrition in the existing driver force in the face of emergencies, and assume that the period of crisis will be relatively short (one to two weeks). Although Exhibit 2.1 was prepared from rough estimates of the likely impact of various measures for improving distribution system productivity, it confirms two of the major intuitive observations of distribution managers regarding operations under emergency conditions:

1. Driver availability is likely to be more critical than vehicle availability; that is, more additional drivers than vehicles are required to meet a specified increase in vehicle mileage.

2. The existing distribution system can support a doubling of vehicle-miles for short periods without requiring additional equipment.

2.6 VEHICLE SITUATION SUMMARY

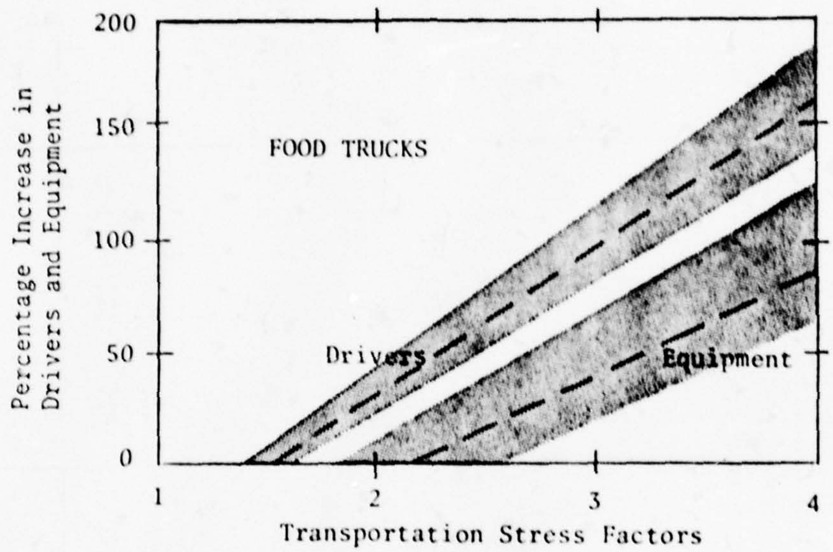
In general, the availability of vehicles during the postattack period will exceed demand. Although damage to automobiles remaining in the risk area at the time of the postulated attack is relatively heavy, there will be an ample supply of automobiles in the postattack period, since under crisis relocation conditions, relocatees take their first automobile to the host area. An estimated 90% of the Colorado Springs relocatee and host area resident families will have access to an automobile in the postattack period.

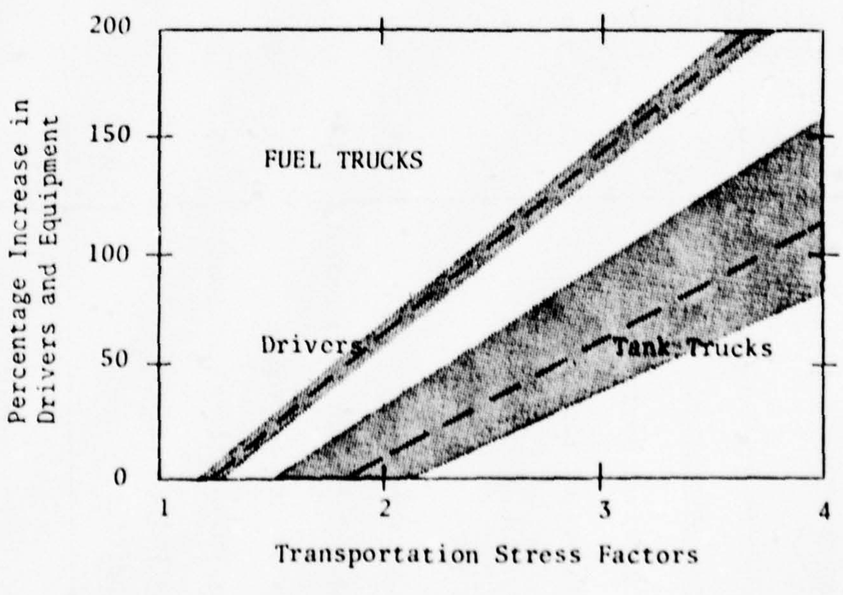
TABLE 2.4

SUMMARY OF POTENTIAL PRODUCTIVITY INCREASES FOR FOOD AND FUEL TRUCKS

EMERGENCY MEASURE	ESTIMATED PERCENT INCREASE IN EFFICIENCY											
	FOOD TRUCKS						FUEL TRUCKS					
	Vehicle Time			Driver Time			Vehicle Time			Driver Time		
	Lower	Mid-Range	Upper	Lower	Mid-Range	Upper	Lower	Mid-Range	Upper	Lower	Mid-Range	Upper
REGULATORY CONSTRAINTS												
Relaxing Driver Restrictions	--	--	--	18%	20%	22%	--	--	--	18%	20%	22%
Relaxing Weight Limitations	4%	6%	8%	4%	6%	8%	--	--	--	--	--	--
EQUIPMENT USE												
Minimizing Down Time	37%	54%	71%	--	--	--	50%	75%	100%	--	--	--
Relaxing Maintenance Requirements	15%	17.5%	20%	--	--	--	5%	7%	9%	--	--	--
Eliminating Light Loads	5%	10%	15%	5%	10%	15%	0%		5%	0%	25%	5%
Shipping Only Full-Pallet Loads	5%	10%	15%	--	--	--	--	--	--	--	--	--
Shipping Only Necessary Commodities	10%	15%	20%	10%	15%	20%	--	--	--	--	--	--
TOTAL	76%	112.5%	149%	37%	51%	65%	55%	84.5%	114%	18%	22.5%	27%

EXHIBIT 2.4: RANGE OF ADDITIONAL DRIVERS AND EQUIPMENT ASSOCIATED WITH TRANSPORTATION STRESS FACTORS





Source: Reference 6.

As indicated in Table 2.3, motor vehicles and rail rolling stock within the risk area will sustain relatively heavy damage; however, most trucks will be moved to the host area during relocation. Therefore, during the immediate postattack period, there will be enough cargo vehicles for the transport of food and other essential goods. In addition, to the extent that operations will permit, certain critical rail rolling stock -- such as switching locomotives -- should also be moved to host area sites during the relocation period. Specialized motor vehicles such as ambulances, dump trucks and debris removal equipment should also be moved to the host area during the relocation period to the extent that this is possible without disrupting risk area operations.

Locomotive spare parts and maintenance manuals should be moved to the host area during the crisis relocation period. Also, parts for trucks and other critical vehicles should be moved to the host area during this time.

In the immediate postattack period, damage to any one of several rail components -- classification yards or rail lines -- could limit overall system capability. Denver and Colorado Springs could expect to undergo a critical curtailment of rail service in the immediate postattack period while the surviving aggregate inventories of locomotives, classification yards, and train crews are fitted back together into an operating system. In the immediate postattack period, the major share of total cargo will move by truck due to the greater survivability and flexibility of this mode.

The most critical problem with transportation equipment under a crisis relocation strategy is likely to be one of organization and coordination. This is expected to be especially true following an attack. Although the surviving vehicle supply is expected to be more than adequate for carrying essential supplies, clear lines of authority and advance planning will be needed to ensure that the vehicles are in the right place at the right time with the right orders.

3. ROAD AND RAIL NETWORKS

3.1 INTRODUCTION

In the postulated nuclear attack on the United States, major road and rail connections will be seriously damaged. Damage to the transportation networks will necessitate detours on the road system and will limit the use of the rail system. Surviving road and rail facilities will be crucial in providing transportation service to the surviving economy and population.

This chapter examines the effect of damage to the transportation network on the travel distances experienced after an attack. The general postattack road situation is considered at the national level by using past studies and a limited series of sample state analyses. A more detailed analysis of postattack road conditions is undertaken using Colorado as an example. Specific commodity movements in Colorado are also studied for a further understanding of postattack transportation problems. The role of truckstops and terminals in the crisis relocation and postattack periods are discussed. In addition, damage to the rail network is assessed at the national level and in Colorado, and various alternatives are evaluated.

3.2 ROAD NETWORK

3.2.1 Nationwide Damage Situation

Previous studies have determined that damage to roads on a national basis is not expected to be great enough to substantially reduce motor transport operations (References 7 and 11). For the range of attacks studied, major highway links were cut in every targeted city; however, in almost every case, alternative detour routes existed around these breaks. Extensive detours could be required in both long- and short-haul shipping following a nuclear attack.

While previous studies have asserted that postattack travel will be possible, the increases in travel distances necessitated by detouring have never been addressed. The following paragraphs outline a rudimentary method of examining both distance and time increases in postattack travel patterns for four states.

3.2.1.1 Travel Distance Increase.

To obtain a rough idea of overall mileage increases following an attack that destroyed the connectivity of the transportation network, the following exercise was completed. Four states were chosen for analysis -- Colorado, Michigan, California and Virginia -- and several geographically diametric pairs of cities within each state were identified. Travel distances between these cities were calculated for the crisis relocation period (reflecting present travel distances on existing roads). Distances were then computed for a postattack situation along routes which avoided blast and fallout areas. Exhibit 3.1 shows examples of alternative routing in the State of Colorado. Rerouting choices confined travel patterns to interstate, U.S., and other principal highways and roads which would provide year-round access for large vehicles. Percent increases in travel distances were then calculated for the postattack period as follows:

State	Percent Increase in Cross-State Travel Distance
Michigan	15
Colorado	21
Virginia	34
California	Cross-state travel interrupted

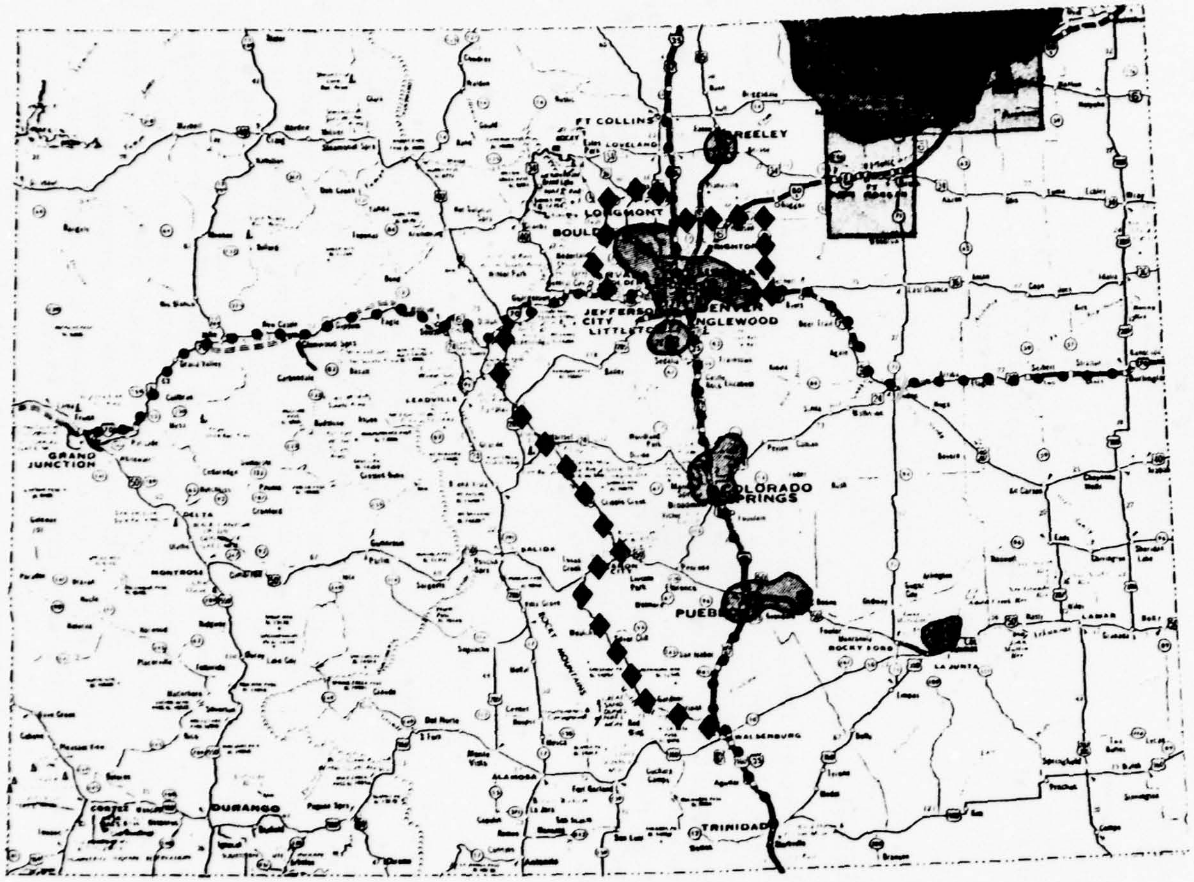
Calculation of increased postattack distances from city to city in California emphasized the virtual impossibility of road travel to some areas after an attack, assuming the attack destroyed all areas identified by DCPA as potential targets (Reference 12). Projected target areas in California include most large urban areas. These areas are located along the major routes of the state, which would also be destroyed. Roads in the less populated, "safe" eastern area of the State are unsuitable for long hauls due to mountainous terrain and weather limitations during the winter; in the southeast, alternate routes simply do not exist. This combination of limited road networks with heavy damage to key intersections in projected target areas and topographic/climatic conditions limiting route choice during part of the year may present problems for alternate routing in other states as well.

3.2.1.2 Travel Time Increases.

Increased travel distances represent only one aspect of postattack travel problems. Detouring around the designated blast and fallout areas necessitates travel on highways that require slower travel speeds than those on the interstate highways commonly used in intercity cargo movement. Thus, calculations of travel time suggest that slower travel, together with increased distances, will compound the difficulties of postattack transport. To examine increased travel time for the four states already studied, simplified assumptions were introduced to reflect speeds on primary and secondary roads: Vehicles on primary

EXHIBIT 3.1

ALTERNATE POSTATTACK HIGHWAY ROUTING IN COLORADO



- ● ● Regular Route
- ◆◆ Detour Route
- ● Blast Area
- ■ Fallout Area

Showing routes and detours between two pairs of cities in Colorado: Grand Junction & Burlington, and Trinidad & Fort Collins.

roads (interstates, U.S. highways and other routes with four or more lanes) were assumed to travel at speeds of 55 miles per hour, while vehicles on secondary highways (principal state routes, two-lane rural roads) were assumed to travel at 45 miles per hour. These assumptions resulted in the following increases in intercity travel time:

State	Percentage Increases in Postattack Travel Time
Colorado	23.0
Michigan	21.7
Virginia	37.8
California	Cross-State travel interrupted

3.2.2 Colorado Situation

Calculations of increased travel distance in the four states provides a very sketchy nationwide picture of postattack transportation problems. To gain a greater insight into these problems, a more detailed investigation of travel on the surviving road network in the sample state of Colorado was completed. As part of this investigation, transportation distances were computed for specific commodities moving from origins within Colorado to survivors scattered throughout the State. This section describes the findings of these studies.

3.2.2.1 Local Travel Distance Increases.

The relative increase in postattack travel distances is greatly colored by the analyst's choice of origins and destinations. Increases in cross-state travel distances will be less marked than the increase in distance encountered in moving from one side of a risk area to another. By way of illustration, distances between seven major highway intersections immediately outside the Denver blast area were computed for both preattack and postattack periods. The resulting 42 pairs of figures (distance from each of seven intersections to each of six other intersections) show a 67.95% increase in travel distances after attack. Thus, while much urban traffic will simply not occur after attack due to population relocation, vehicle impoundments, fuel shortages, etc., travel between the peripheries of the blast areas will experience a much greater percentage increase than cross-state travel.

Distance increases reflect the connectivity of the transportation network, and especially the location of nodes within or outside blast and fallout areas. Colorado provides an example of the variability of travel distances encountered in rerouting intercity travel. Intercity travel increases within the State range from 18% (Grand Junction to Burlington) to 48% (Fort Collins to Trinidad). Complete inaccessibility

also threatens to be a postattack problem for some areas. The non-blast areas between Pueblo and Denver, for example, may be isolated in times of inclement travel conditions, as all major access roads to these areas run into the blast zones of Denver, Colorado Springs and Pueblo.

3.2.2.2 Postattack Increases in Colorado Commodity Movement Distance.

The increases in cross-state and intercity travel distances are of interest only insofar as they provide insights into the likely increases encountered in transporting essential commodities following an attack. To address this problem directly, origins and destinations of essential commodity movements should be traced before and after the postulated attack, and increased transportation requirements should be computed on a commodity-by-commodity basis. Ideally, this exercise should be undertaken at the national level. However, such an investigation was beyond the scope of the current study. Nonetheless, the current study traced movement of three critical commodities -- wheat, petroleum and milk -- within Colorado before and after the postulated attack. Distances from product sources to consumers were calculated along existing routes and weighted by the amount of the product moving from each source. Following this, postattack distances from surviving sources to the relocation centers were measured over the shortest routes on surviving roads, weighted by movement quantity, and compared with preattack distances. The results of this comparison are tabulated below.

Product	Percent Increase in Travel Distance
Wheat	25%
Milk	90%
Petroleum (best case)	22%
(worst case)	41%

The 25% increase in wheat transportation distance represents the transportation of wheat from the major wheat-producing counties in the eastern part of the State to Canon City, a relocation center, and from the western wheat-producing counties to Grand Junction. The figure does not include calculations for wheat entering or leaving the State. However, a concurrent SYSTAN study (Reference 30) shows that most of the wheat and cereal products consumed in Colorado are produced and processed within the State. Distances for milk transport were arrived at in a similar way, resulting in a 90% increase in travel distance. A major factor in this relatively large increase is the need to ship quantities of fresh milk from Colorado to Idaho and Utah for drying in the postattack period. This need stems from the destruction of most of Colorado's milk-processing facilities and the advantages of dried milk over perishable fresh milk in the postattack period.

Two figures are presented for petroleum transport increases. The "best case" assumes that petroleum can be received from La Junta and Fort Collins pipeline terminals. These terminals are both on the edge of the blast areas; they may or may not be destroyed, damaged or inac-

cessible due to road damage after attack. The "worst case" assumes that petroleum cannot be received from either of the terminals due to one of more of these problems. In this case, trucks would be used to transport petroleum from surviving refineries outside the State.

The above figures represent very rough calculations and are proposed only as guidelines for further study in the area of postattack commodity transport. A knowledge of the nationwide origins and destinations of critical commodity movements would be required for comprehensive postattack transport planning, including the allocation of food, fuel and other critical commodities. The calculations for specific commodities in Colorado suggest the direction for possible future research at the national level.. Because national shortages will have an impact on the local availability of such critical commodities as food and fuel, a study of nationwide commodity movements is recommended as the next step in the investigation of postattack transportation requirements.

3.3 TRUCKSTOPS AND TERMINALS

In the early 1960's, the motor carrier displaced the railroad as the dominant mode of intercity freight transportation, measured in terms of total tonnage carried. As intercity truck traffic has increased in importance, a network of support facilities has grown up alongside the nation's interstate highway system. These support facilities, commonly called truckstops, are self-contained units capable of providing a variety of fueling and support services in times of emergency. This section provides an overview of the nation's truckstop network, discusses the potential role of these truckstops in the event of a crisis relocation, assembles a state-by-state inventory of individual truckstops, and assesses the vulnerability of these truckstops to damage from nuclear attack. A more thorough treatment of current and potential services provided by truckstops may be found in Volume III, The Role of Truckstops in Crisis Relocation. This more detailed treatment also discusses the creation of a truckstop owners' emergency organization and supplies an itemized listing of major U.S. truckstops.

3.3.1 Overview of the Truckstop Network

A survey conducted for SYSTAN by the National Transportation Fueling Corporation identified a total of 2,682 truckstops scattered throughout the U.S. Exhibit 3.2 shows the location of these truckstops along major intercity shipping routes. The typical truckstop is open 24 hours a day, seven days a week, 52 weeks a year, and offers far more than fuel to its trucking customers. In addition to fuel, truckstops offer garage and maintenance facilities, overnight parking space, sleeping accomodations, restaurant operations, retail stores, and a variety of communications services. The location of the listed truckstops has also been plotted on detailed state and national maps in this reference.

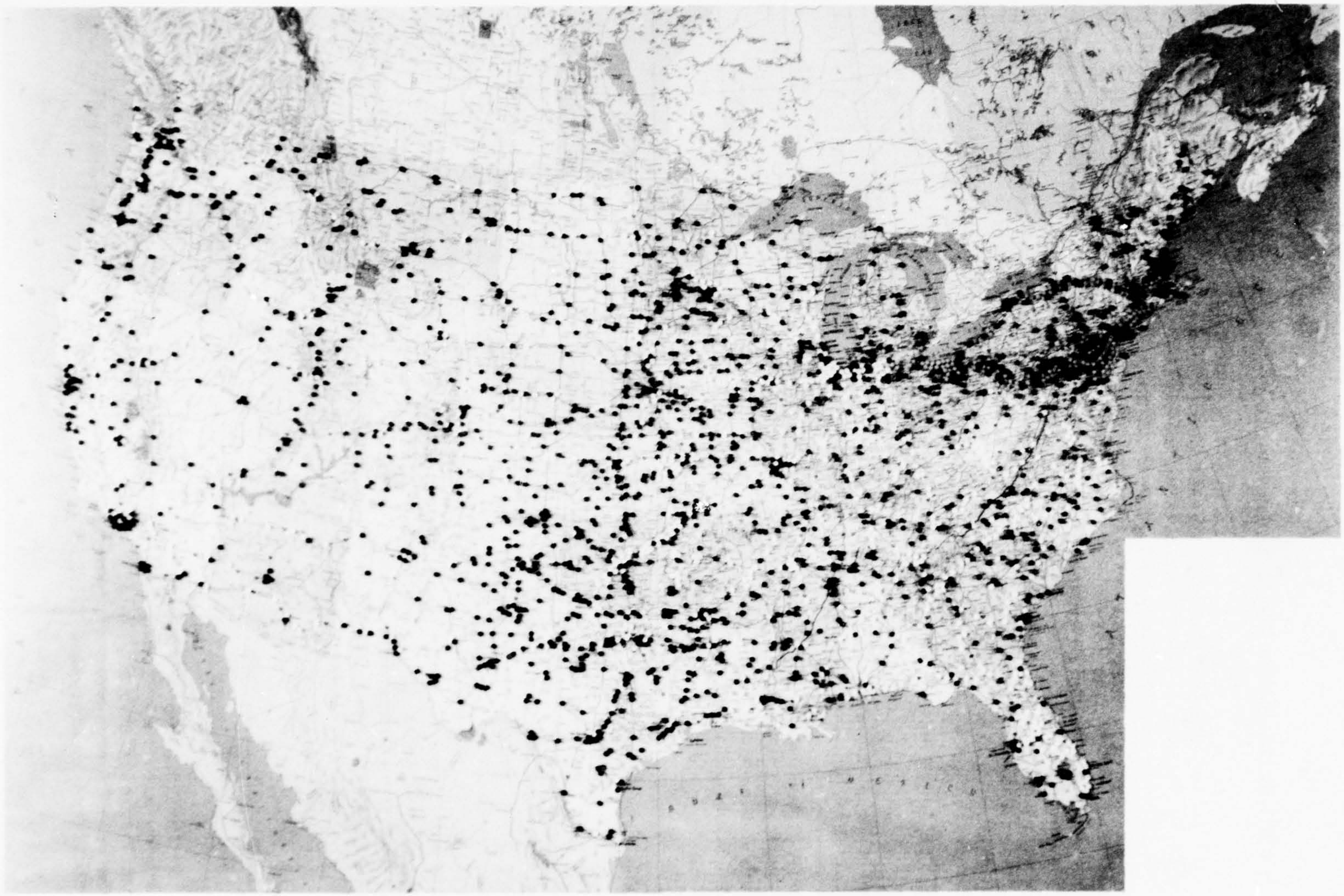


EXHIBIT 3.2: U.S. TRUCKSTOP LOCATIONS

3.3.2 Relative Importance of Truckstops in Intercity Cargo Movement

It is estimated that truckstops supply about 68% of all diesel fuel used by tractor-trailer combinations in intercity operations and about 56% of total diesel fuel used in both intercity and urban operations. Most large and many medium-size common carriers (classified as Class I and Class II by the Interstate Commerce Commission) transporting general freight nationally or regionally have terminals along their routes which provide some of the same services for their own drivers and vehicles as truckstops provide for other trucks. However, relatively few general freight carrier firms provide sleeping facilities for their drivers. Moreover, economic considerations and union restrictions prevent 24-hour operation of these terminals, which are often closed over weekends and holidays.

The principal users of the truckstops are Class I and II carriers of special commodities and household goods, Class III general freight carriers (under $500,000 revenue), and interstate carriers. These carriers do not usually have extensive terminal networks, and may have only a home-base terminal where the units are serviced, refueled and repaired. Large general carriers also use the truckstops on weekends and holidays and at other times when their own terminals are closed or inconveniently located.

3.3.3 Current Emergency Role of Truckstops

The proximity of the nation's truckstops to the interstate highway system, coupled with the wide range of services offered by these truckstops, makes the truckstop an ideal source of emergency aid for truckers and travelers on interstate and other major highways. During the severe snowstorms that blanketed the northeastern United States during the winters of 1976-77 and 1977-78, truckstop operators housed stranded travelers, coordinated truck convoys to ensure the safety of commercial cargo, monitored CB channels to identify critical situations, organized rescue operations, used snowmobiles to take fuel to stranded vehicles, and performed many other activities to protect the traveling public and keep commercial traffic moving.

3.3.4 Potential Role of Truckstops in Crisis Relocation Planning

The relative invulnerability of truckstops to nuclear attack, coupled with their importance in the day-to-day movement of intercity traffic, make them a pivotal resource in any crisis relocation plan. The role of risk area and host area truckstops under crisis relocation conditions is discussed below.

3.3.4.1 Risk Area Truckstops.

Certain truckstops located within risk areas would be designated as critical and would remain open with minimal staffing during and after relocation (see Volume III). Other risk area truckstops would remain open so long as their fuel supplies last during the three-day relocation effort and shut down on the final day of relocation, reporting any remaining fuel supplies to appropriate officials. Mechanics and other staff from those risk area truckstops to be closed following relocation would be reassigned to host area truckstops, which would control the bulk of intercity motor carrier movement during and after relocation.

3.3.4.2 Host Area Truckstops.

In keeping with the general desire to make maximum use of existing channels in developing crisis relocation plans, truckstops located outside risk areas should be designated as emergency control centers for intercity cargo movement. In addition to their traditional roles as fueling points, these control centers would also act as:

- Checkpoints for the rerouting or reassignment of essential shipments;

- Interim consignment points for non-essential shipments;

- Relay points for drivers;

- Coordination and reassignment points for cabs and drivers; and

- Central assignment points for mechanics.

3.3.5 <u>Relative Vulnerability of U.S. Truckstops</u>

One important criterion for measuring the potential utility of truckstops in times of emergency is their vulnerability to nuclear attack. In order to assess this vulnerability, SYSTAN assembled data from each of 2,682 truckstops for purposes of damage assessment analysis. For each truckstop, the following information was assembled:

1. Name;

2. Address;

3. Telephone number; and

4. Fuel brand sold.

Each truckstop was further classified as either Primary (P) or Secondary (S) according to the following criteria:

P - Primary Locations

- Extensive parking (at least 100 units at highway locations)
- Restaurants (large, approximately 100 seats or more)
- Sleeping accomodations available (except toll road plazas)
- Full mechanical facilities
- Full communications facilities (including wire service)
- Ample fuel storage capabilities (at least 50,000 gallons)

S - Secondary Locations

- Adequate parking (at least 25 units for urban locations and 50 units at highway locations)
- Restaurants (smaller scale but adequate for location; approximately 30-50 seats)
- Basic mechanical facilities
- Basic communications facilities (may lack wire services)
- Sleeping accomodations (either directly available or adjacent)
- Adequate fuel storage capability (various from 20-25,000 gallons and upward)

The individual truckstop information, which was assembled on a far broader scale than was previously available from any source, has been coded and computerized for easy sorting and access. Volume III contains a computer-produced listing of characteristic data for each truckstop arranged by state. These data were employed in a damage assessment analysis in which the geographic locations of each of the 2,682 truckstops surveyed were compared with the blast and fallout diagrams contained in the DCPA publication entitled "High Risk Areas" (Reference 12). The results indicated that 1,840 (68.6%) of the truckstops would remain undamaged, while 23 (.86%) would sustain only slight damage. It was also determined that 757 (28.2%) of the truckstops were located close enough to the center of the blast zones that they would not survive the postulated attack. An additional 62 truckstops (2.3%) were unaffected by the blast but subject to fallout effects. The truckstop vulnerability assessment is summarized on a state-by-state basis in Table 3.1. Since over 69% of all U.S. truckstops can be expected to survive a nuclear attack with either no damage or very slight damage, it can be seen that truckstops constitute a relatively invulnerable element of the nation's transportation network. The high survival rate postulated by this figure suggests the utility of truckstops during both the crisis relocation and postattack periods. To make maximum use of this emergency resource, an attempt should be made to form a voluntary organization of truckstop owners capable of providing fueling capability for vehicles and havens of rescue for drivers and passengers in times of crisis. More details regarding the nature and mission of such an organization may be found in the concurrent SYSTAN investigation "The Role of Truckstops in Crisis Relocation," included as Volume III of the current report.

TABLE 3.1: TRUCKSTOP VULNERABILITY ASSESSMENT

State	Total Stops	Unaffected by Blast or Fallout	Slight Blast Damage	Severe Blast Damage	Fallout Effects Only	Percent Surviving & Immediately Available Total	Primary	Secondary
Alabama	49	37	1	11	--	77.6	80.8	73.9
Alaska	11	11		--	--	100	100	100
Arizona	28	20		8	--	71.4	78.9	55.6
Arkansas	49	33	2	12	2	71.4	61.5	82.6
California	123	49	2	66	6	41.5	41.8	41.2
Colorado	66	53	1	11	1	81.8	75.0	84.8
Connecticut	16	--		13	3	0.0	0	0
Delaware	6	1		4	1	16.7	33.3	0
Florida	82	58		24	-	70.7	70.6	71.0
Georgia	57	45		12	-	78.9	76.7	81.5
Idaho	38	35		3	-	92.1	75.0	96.7
Illinois	80	43		35	2	53.8	52.2	55.9
Indiana	75	50		25	-	66.7	67.6	65.8
Iowa	87	73		14	-	83.9	75.9	87.9
Kansas	100	76	1	21	2	77.0	74.1	78.1
Kentucky	35	29	1	5	-	85.7	90.0	80.0
Louisiana	46	32		14	-	69.6	50.0	82.1
Maine	23	16		7	-	69.6	80.0	66.7
Maryland	20	7		9	4	35.0	30.0	40.0
Massachusetts	36	5		25	5	13.9	31.3	0
Michigan	51	30		21	-	58.8	45.5	71.4
Minnesota	71	49		8	4	69.0	72.2	96.8
Mississippi	63	55		8	-	87.3	73.3	91.7
Missouri	89	56	1	22	10	64.0	38.9	70.4
Montana	50	33	6	11	-	78.0	90.9	74.4
Nebraska	72	57		11	4	79.2	76.5	80.0
Nevada	29	21		8	-	72.4	63.6	77.8
New Hampshire	9	8		1	-	88.9	--	88.9
New Jersey	35	4		29	2	11.4	6.7	15.0
New Mexico	46	31	2	13	-	71.7	60.0	75.0
New York	72	46		24	3	63.9	60.6	65.0
North Carolina	53	40	1	12	-	77.4	83.3	74.3
North Dakota	31	20	1	7	3	67.7	72.7	65.0
Ohio	95	60		35	-	63.2	60.4	66.7
Oklahoma	97	77		20	-	79.4	64.5	86.4
Oregon	41	29	1	11	-	73.2	66.7	74.3
Pennsylvania	124	79		38	7	63.7	71.1	61.0
Rhode Island	4	--		3	1	0.0	--	0
South Carolina	39	26		13	-	66.7	66.7	66.7
South Dakota	41	29		11	1	70.7	44.4	78.1
Tennessee	55	44		11	-	80.0	61.1	89.2
Texas	257	195	3	48	1	77.0	60.9	80.6
Utah	37	27		10	-	73.0	33.3	80.6
Vermont	10	8		2	-	80.0	--	80.0
Virginia	43	31		12	-	72.1	64.0	83.3
Washington	46	32		14	-	69.6	40.0	68.2
West Virginia	18	13		5	-	72.2	58.3	100
Wisconsin	43	33		10	-	76.7	53.3	89.3
Wyoming	34	24		10	-	70.6	55.6	76.0
Total	2,682	1,840	23	757	62			
Percent	100%	68.6%	0.86%	28.2%	2.3%	69.5%	61.2%	73.7%

3.4 RAIL NETWORK

Rail transportation lacks the flexibility of road transportation, and the nation's rail network has far fewer alternative routes than the road network. As a consequence, the rail network will prove less useful than the road network after an attack which damages links in both networks. However, railways will still play a significant part in transportation of commodities where such transport is possible. The following sections survey the national damage situation, the Colorado damage situation, and alternatives for use of the railway network after the postulated attack.

3.4.1 Nationwide Damage Situation

It is expected that from 35% to 55% of U.S. rail facilities will remain undamaged. Specifically, according to earlier studies, the percentage of preattack facilities inventory expected to survive is: switching mechanisms, 37%; classification yards, 41%; railroad repair shops, 53%.

In general, however, short-term rail disruption is more serious than indicated by percentage survival of various categories of equipment and facilities because these percentages "...do not reflect what happened at critical points within the system" (Reference 8).

"In analyzing all of the components of the railroad transportation system, no evidence was found to suggest that any single component would be the most limiting component for a wide variety of attack conditions. In some geographical areas, the lack of adequate classification yards would limit system capability; in other areas, the lack of rail lines would be a limiting factor" (Reference 11).

Data based on the UNCLEX-Charlie attack indicates that the accessibility of switching and line-haul locomotives, on the average, would increase from 30% to 50% between D+1 and D+30. The accessibility of switching locomotives alone would increase from about 25% to about 40% between D+1 and D+30. Indications are that debris removal will be one of the major tasks to be carried out in the process of increasing railroad postattack operational capability. In general, it appears that railroads could be 30% to 50% operational, but with reduced efficiency, within 30 days after an attack by using detour routing where bridges are destroyed.

3.4.2 Colorado Situation

At the local level, earlier studies indicate that most major urban areas would have only limited rail accessibility. "In most target areas rail lines would be blocked by debris or rubble at many locations where the rail line itself would probably be undamaged. In the attacks on

metropolitan areas, it appeared that large sections of undamaged track would be closed because of debris." (Reference 11)

In Colorado, all of the railroad terminals in Denver and Colorado Springs would receive moderate to heavy blast damage. The yards of the lines serving Denver (i.e., Burlington Northern-Colorado and Southern, Denver Rio Grande and Western-Rock Island, Union Pacific and A.T. & S.F., all sustain blast overpressures of more than 10 psi. The lines serving Colorado Springs (i.e., Denver Rio Grande and Western, and A.T. & S.F.) sustain blast overpressures of more than 5 psi. A sketch of the Colorado rail network is shown in Exhibit 3.3. As indicated above, due to relatively heavy damage to rail facilities, Denver and Colorado Springs could expect to undergo a critical curtailment of rail service in the immediate postattack period, while the surviving aggregate inventories of classification yards, tracks, locomotives, and train crews are fitted back together into an operating system.

Within the Denver area, shops and depots would be heavily damaged by blast and fire. Signals would be damaged and there would be no electric power. Toppled fuel tanks would cause added fire damage, as would overturned petroleum product tankcars. Approximately 80% to 90% of the freight-cars would be inaccessible -- destroyed by blast or fire or blocked by debris. Rolling stock on industry tracks would be particularly hard-hit because of their proximity to buildings which would be destroyed by blast or fire. Boxcars are generally completely destroyed at 5-6 psi (References 2 and 15). Railroad locomotives survive better, but many would be rendered unusable after the attack as a result of debris on rail lines.

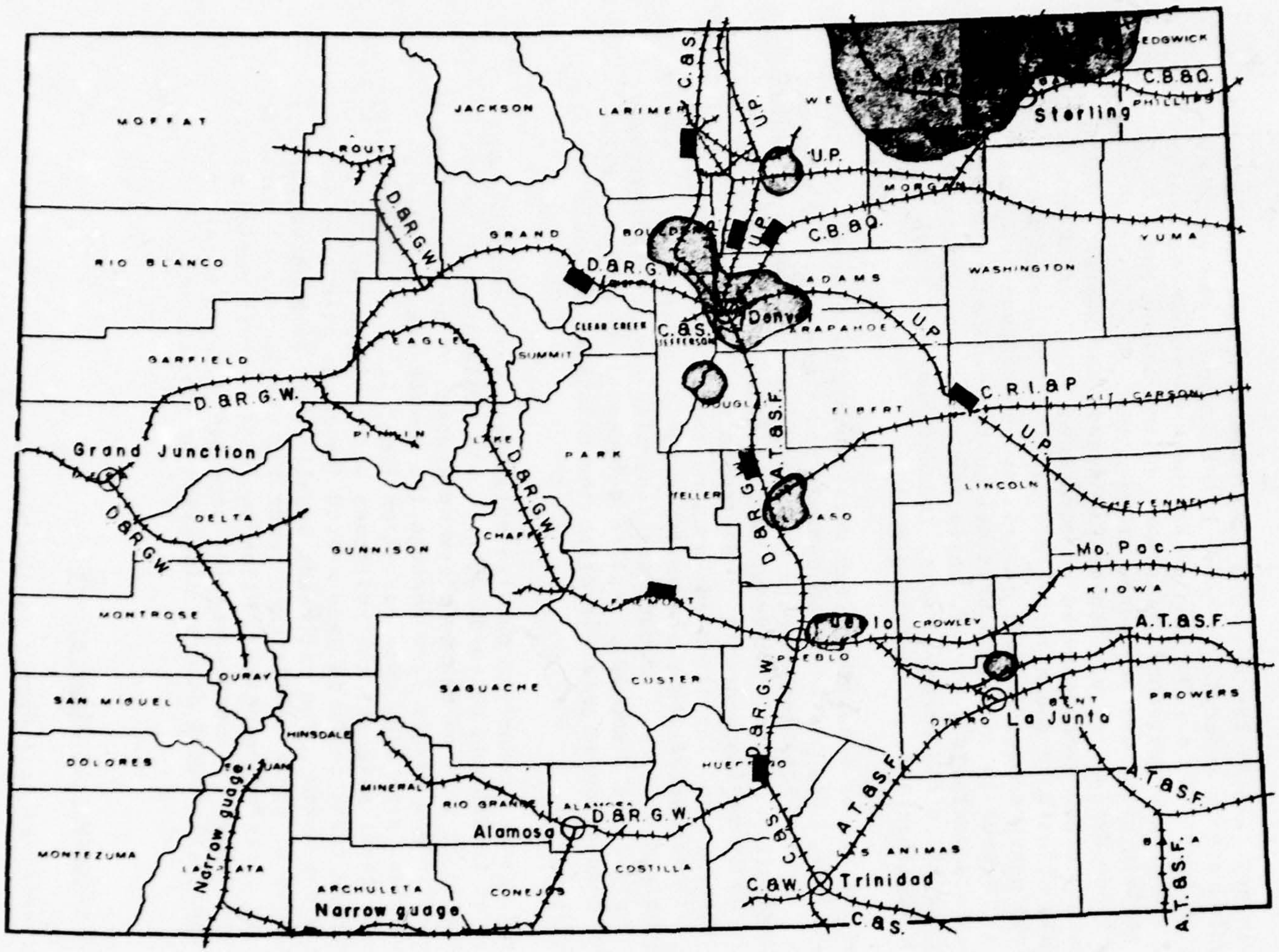
Railroad tracks themselves survive relatively well, except that in the vicinity of BN-C&S and UP yards which would sustain some damage. The main problem is that of debris blocking tracks. Debris could probably be cleared from a single line through the Denver area in a relatively short time, depending upon radiation limitations. Railroad officials estimate that, with all the railroads working together, 5-10 miles of new temporary track could be laid around the devastated area in approximately one month. The railroads usually have on hand at various locations panels of track or flatcars ready for use in time of washouts, derailments or other emergencies. Major postattack construction of new track sections would, of course, require more workers, materials and time than repair after most natural disasters or derailments.

3.4.3 <u>Identification of Alternatives</u>

3.4.3.1 Movement of Rail Panels to the Host Area.

Railroads usually have flatcars preloaded with rail panels (rails on ties) spotted at various locations in order to repair track damage caused by washouts and derailments. Where such preloaded railcars are in the risk area, they should be moved to the host area during the crisis relocation period. In addition, where possible, replacement

EXHIBIT 3.3: COLORADO RAIL NETWORK



Blast area

Fallout area

Blast and fallout area

Potential emergency railyards

rails not in panel form could be loaded on flatcars and moved to the host area during the crisis relocation period.

3.4.3.2 Survey of Little-Used Track for Use in Postattack Repair.

During the precrisis period, some preliminary surveys can be made of the little-used track or sidings in the risk and host areas which may not be critical to goods movement and which could be used for repair of damaged track sections in the postattack period.

3.4.3.3 Movement of Emergency Generating Equipment to Host Area.

Loss of electric power would hamper or prevent operations in most industries, including railroads. Power would be particularly vital for classification yards and signaling systems if rail operations are to be continued. Where possible (without disruption of essential service), emergency power generating equipment should be moved to the host area during the relocation period.

3.4.3.4 Movement of Critical Rolling Stock to Host Area.

As noted in Chapter 2, during the crisis relocation period selected critical rolling stock (such as engines) should be moved from the risk areas to the host areas. Most railroads have double track every few miles; under conditions in which fewer than normal trains are being operated, some of these double-track sections could be used for spotting or "pulling out" critical rolling stock. Where available, sidings are preferable for this purpose, as their use does not interfere with normal train operations. Possible pullout locations on each railroad serving Colorado Springs are discussed below and indicated on the rail system map of Exhibit 3.3.

Union Pacific

Union Pacific tracks run north and east from Denver. Engines or other critical rolling stock could be set off at several places north of Denver, including Ault, Nunn and La Salle in Weld County. Union Pacific has passenger train pullouts at these points. It should be noted, however, that La Salle is at the edge of the Greely risk area. On the Union Pacific track between Denver and Salina, Kansas, rolling stock could be set out at Limon in Lincoln County. The Limon location could also be used for the same purpose by Rock Island Railroad, which runs east from Colorado Springs.

Denver, Rio Grande and Western (D&RG-W)

D&RG-W lines run west and south from Denver. Engines or other critical rolling stock could be set off at several places west of Denver, including Winter Park, Fraser, Tabernash, and Granby and Sulphur Springs in Grand County. On the D&RG-W track between Denver and Colorado Springs, rolling stock could be set out at Monument in El Paso County. On the track going south from Colorado Springs, rolling stock could be pulled out at Walsenburg in Huerfano County, south of Pueblo.

Atchinson, Topeka and Santa Fe (AT&SF)

AT&SF lines run south out of Denver through Colorado Springs to Pueblo and then east to Kansas. AT&SF tracks also run from Trinidad east through La Junta to Kansas. Engines or other critical rolling stock could be set off at Monument in El Paso County. A double set of tracks runs the entire distance from Denver to the Air Force Academy.

Burlington Northern-Colorado Southern (BN-CS)

The BN-CS tracks run north and west out of Denver. Engines and other critical rolling stock could be set off at Loveland and Fort Collins north of Denver in Larimer County. On the BN-CS track west of Denver, rolling stock could be set out at Tenville, Hudson, Keenesburg, Crest and Wiggins. Also, BN-CS uses the Santa Fe track between Denver and Colorado Springs.

In general, railroad officials do not see a problem in having space to set out critical rolling stock. The view of most railroad officials interviewed is that "we will find a place to put it." Most railroads have double track or sidings every few miles in order to allow trains to pass. Also, in time of emergency, there would be no need to use only company-owned track. In fact, under normal conditions, it is common practice for railroads to have agreements with each other for the use of their track.

3.4.3.5 Identify Key Host-Area Railroad Terminals and Plan for Expansion.

The problem of loading and unloading freight-cars could be a very serious one if terminals are badly damaged or destroyed in an attack on urban centers. Key host-area terminals should be identified and their expansion planned, including planning for the provision of materials-handling equipment.

In Colorado, several possible transfer points outside the risk area have been identified. In the preceding subsection, various critical rolling stock pullout points along the route of each railroad serving Denver and Colorado Springs have been identified. Some of these points could serve as key terminals for loading and unloading cargo in the postattack period when risk area terminals are inaccessible. These possible locations are listed in Table 3.2 and listed in Exhibit 3.3.

TABLE 3.2

HOST AREA RAIL TERMINALS WHICH COULD BE USED FOR INTERMODAL TRANSFER

Railroad	Track Direction from Risk Area	Location
Denver		
Burlington Northern-Colorado and Southern	North West	Loveland and Ft. Collins, Larimer County Tenville and Hudson, Weld County
Denver Rio Grande & Western Rock Island	West South	Winter Park and Fraser, Grand County Monument in El Paso County
Union Pacific	North East	Ault and Nunn, Weld County Limon, Lincoln County
Atchison, Topeka & Santa Fe	South	Monument, El Paso County
Colorado Springs		
Denver Rio Grande & Western-Chicago Rock Island & Pacific	South West	Walsenburg, Huerfano County Limon, Lincoln County
Atchison, Topeka & Santa Fe	North	Monument, El Paso County

3.5 SUMMARY

3.5.1 Road Network

Earlier studies have determined that, at the national level for the range of attack studied, major rail and highway links were cut in every major city targeted. It was determined, however, that detour routing around damaged areas could usually be found.

In the past, relatively little work has been done to estimate the additional travel distance required in detouring around damaged roads. In a preliminary sample analysis of four states, SYSTAN determined that postattack increases in interstate mileage ranged from 15 to 34 percent. In some states, such as California, certain regions of the state are liable to be effectively cut off from road and rail access to other regions.

The damaged road network will require that in many instances secondary routes be taken; since average speeds will be less than those on major routes, overall trip time will be increased. Increases in a sample of three states ranged from 22% to 38%.

A preliminary analysis of Colorado postattack commodity movements revealed transport distance increases of 25% for wheat, 22% to 41% for petroleum, and 90% for milk. However, this analysis was limited in scope to the Colorado Springs study area. A nationwide commodity movement model is needed as a basis for quantifying the increases in transportation distances, vehicle requirements, and fuel consumption resulting from a range of different attack patterns.

3.5.2 Truckstops and Terminals

The more than 3,000 truckstops located along the nation's highway system are important resources in crisis relocation and postattack planning. In the two decades since they have become a prominent part of the intercity transportation picture, truckstops have proven themselves to be an invaluable source of emergency assistance to travelers and commercial truckers in natural disasters. The relative invulnerability of truckstops to nuclear attack coupled with their importance in the day-to-day movement of intercity traffic make them a valuable resource in any crisis relocation plan. Under crisis relocation conditions, certain truckstops located within the risk area would be designated as critical and would remain open with minimal staffing during and after relocation. Other risk area truckstops would remain open so long as their fuel supplies last during the three-day relocation effort and shut down on the final day of relocation. Truckstops located within the host areas would be designated as emergency control centers for intercity cargo movement. In addition to their traditional roles as fueling points, these control centers would also act as: (1) checkpoints for rerouting or reassignment of essential shipments; (2) interim consignment points for non-essential shipments; (3) relay points for drivers;

(4) coordination and reassignment points for cabs and drivers; and (5) central assignment points for mechanics.

To make maximum use of truckstops as an emergency resource, an attempt should be made to form a voluntary organization of truckstop owners capable of providing an emergency fueling capability for vehicles and havens of rescue for drivers and passengers in times of crisis. Such an organization could add several billion dollars to the emergency preparedness posture of the country at little cost to the government, and help ensure that the nation's most versatile mode of freight transportation would continue to operate efficiently in times of stress.

3.5.3 Rail Network

Earlier studies indicate that if an attack were to occur, nationwide rail facility damage would be relatively heavy, with 41% of the classification yards and 53% of the repair shops surviving. Overall, it appears that the rail system could be 30% to 50% operational, but with reduced efficiency, within 30 days after the postulated attack.

In Colorado Springs, rail facilities would also be seriously damaged by the attack, but Colorado Springs facilities would be less severely damaged than those in Denver. In general, short-term rail disruption is more serious than indicated by percentage survival of various categories of equipment and facilities because these percentages do not reflect what happens at critical points within the system. During the immediate postattack period, railroad operation will be impaired due to damage to critical components and to the inaccessibility of undamaged track. Due to the lack of flexibility of rail transportation, trucks will carry a major share of the intercity cargo in the immediate postattack period.

The simplest transportation alternative that might be adopted following a nuclear attack would entail the use of detour routings to avoid roadways and railways that have been damaged by blast or blocked by debris. The use of detour routings could be required in both long-haul and short-haul shipping following a nuclear attack.

Key host area terminals which could be expanded in times of crisis should be identified in the preattack period, and plans for the expansion of these terminals should be incorporated in the appropriate host area planning documents. Terminals outside the risk area which may be used as intermodal transfer points should also be identified and plans made for their expansion.

During the crisis relocation period, such critical rolling stock as switch engines and line-haul locomotives should be moved from the risk areas to the host areas. Possible host area locations where this critical rolling stock may be stored should be identified in the appropriate planning documents.

Railroads usually have flatcars preloaded with rail panels (on ties) spotted at various locations in order to repair track damage caused by washouts and derailments. Where such panels are in the risk area, they should be moved to the host area during the crisis relocation period. In addition, where possible without disruption of essential service, emergency power-generating equipment should be moved to the host area during crisis relocation.

In general, there will be considerable curtailment of rail service during the immediate postattack period due to damage and debris, and a greater share of the nation's cargo will initially be carried by the more flexible trucking system. Adequate planning and training in the preattack period and efficient management of vehicles and facilities in the postattack period will be essential to the successful operation of the nation's rail network following an attack.

4. FUEL FOR TRANSPORTATION

This section summarizes fuel distribution patterns before, during and after relocation and assesses the attack damage suffered by the reconfigured distribution system. Fuel needs during the postattack period are estimated and alternative means of meeting these needs are identified and evaluated. This section focuses on the distribution of those petroleum products most important to the transportation industry: gasoline and diesel fuel. The reader interested in a discussion of the total petroleum distribution system from a defense standpoint is referred to the report, "Vulnerability of Total Petroleum Systems," prepared for the Defense Civil Preparedness Agency by the U.S. Department of the Interior (Reference 16).

4.1 OVERVIEW OF THE DISTRIBUTION SYSTEM

Both the United States and the State of Colorado rely heavily on outside sources for their petroleum supply. Current U.S. petroleum consumption rates are about 16 to 17 million barrels per day; of this, about 8-1/2 million barrels per day are from domestic production, while the remainder is imported. Alaska will add about one-million barrels per day to domestic production figures.

Only about 30 percent of Colorado's gasoline needs are met from within the State; the remainder is imported from Kansas, Montana, Texas and Wyoming (Reference 15). At the local level, Colorado Springs must satisfy all its fuel needs by importing fuel from Denver, either by tank truck or pipeline. The flow of fuel into Colorado Springs is graphed in Exhibit 4.1.

4.1.1 Colorado Supply and Distribution

4.1.1.1 Crude Supply.

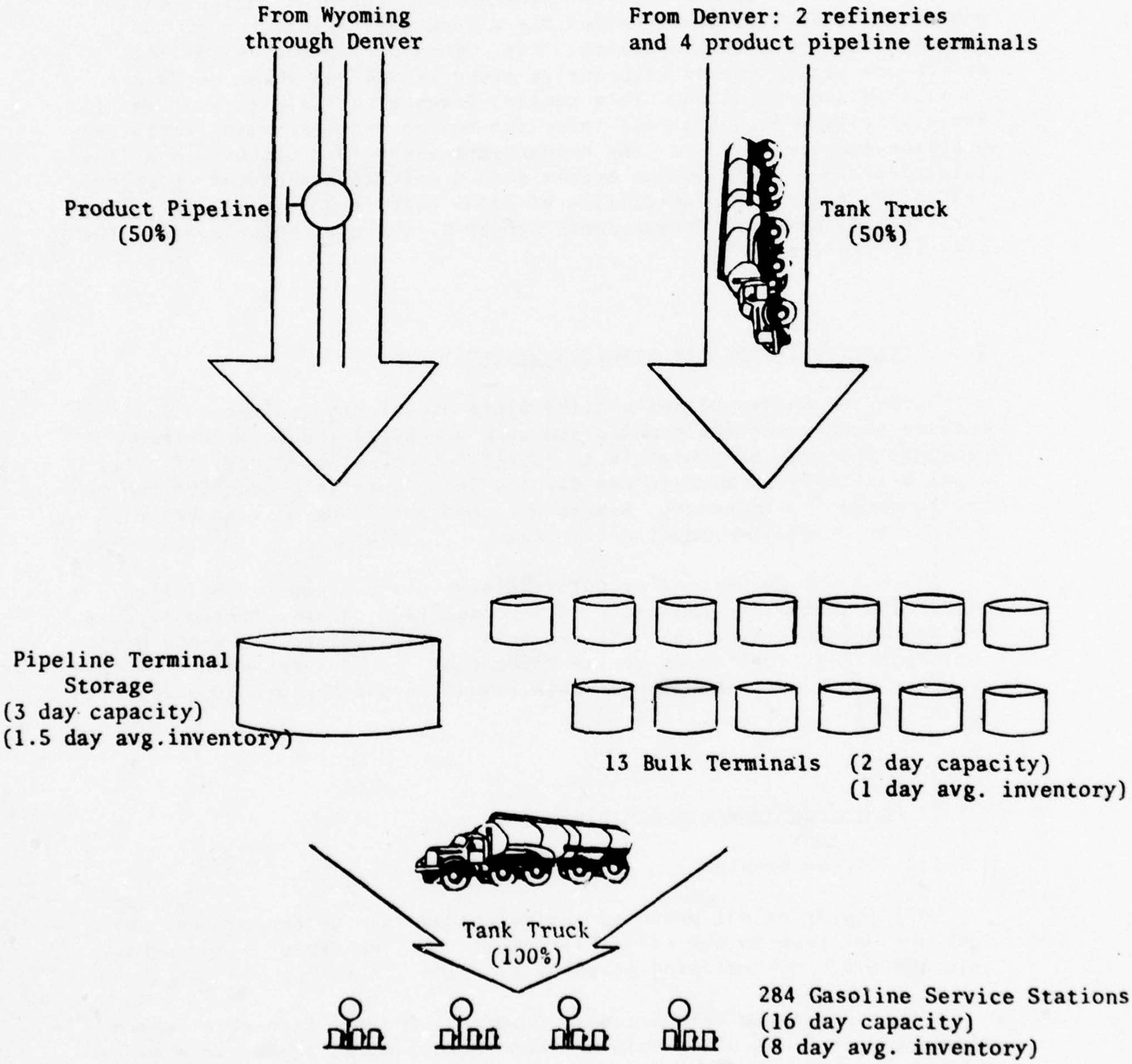
All the crude oil produced and refined within Colorado moves by tank car or truck to the refineries, while all the crude oil brought into the State for refining moves by pipeline.

There are three refineries in Colorado, the two largest of which are in Denver. Operating data on these Colorado refineries is shown in Table 4.1. These three refineries can accommodate about 60,000 barrels per day of crude oil, and typically produce an output of about 30,000 barrels per day of gasoline, with diesel and other products making up the balance.

EXHIBIT 4.1

DISTRIBUTION OF PETROLEUM PRODUCT

IN EL PASO COUNTY, COLORADO (COLORADO SPRINGS)



Capacities and Inventories Measured in Terms of
1974 Daily Consumption Rate of 328,767 gal/day.

TABLE 4.1

SURVEY OF OPERATING REFINERIES IN THE U.S. AND COLORADO

(STATE CAPACITIES AS OF JAN. 1, 1975)

State	No. plants	Crude capacity* b/cd	Crude capacity* b/sd
Alabama	3	34,375	37,947
Alaska	4	66,050	69,520
Arizona	1	4,000	4,211
Arkansas	4	60,715	62,536
California	36	1,900,640	1,985,140
Colorado	3	60,000	62,500
Delaware	1	140,000	150,000
Florida	1	5,700	6,000
Georgia	2	18,000	19,789
Hawaii	2	85,000	89,473
Illinois	11	1,168,150	1,224,658
Indiana	8	563,275	595,973
Kansas	11	447,180	466,129
Kentucky	3	164,000	168,900
Louisiana	19	1,729,575	1,802,149
Maryland	2	26,500	28,211
Michigan	6	149,082	151,379
Minnesota	3	199,300	204,000
Mississippi	5	289,500	304,737
Missouri	1	107,000	107,000
Montana	8	157,206	164,227
Nebraska	1	5,000	5,500
New Jersey	4	539,000	562,764
New Mexico	7	103,061	111,135
New York	2	111,385	114,500
North Dakota	3	58,658	60,263
Ohio	7	589,770	614,500
Oklahoma	12	499,815	515,145
Oregon	1	14,000	14,740
Pennsylvania	11	757,020	796,415
Rhode Island	1	7,500	10,000
Tennessee	1	43,900	44,800
Texas	45	3,929,430	4,096,965
Utah	6	143,000	117,068
Virginia	1	53,000	54,000
Washington	7	364,000	379,816
West Virginia	3	19,750	20,500
Wisconsin	1	45,000	46,400
Wyoming	12	186,870	194,660
Total	259	14,845,407	15,463,650

*State totals include figures converted to calendar-day or stream-day basis.

Refineries in Colorado

Plant	Location	Crude Capacity (bbl/cal. day)	Gasoline Output Capacity (bbl/cal. day)
Conoco	Denver	30,000	14,500
Refinery Corp.	Denver	20,500	10,000
Gary Western	Grand Junction	9,500	6,900
	TOTAL	60,000	31,400

Source: The Oil and Gas Journal, April 7, 1975 and SYSTAN Interviews.

4.1.1.2 Product Distribution.

Four pipelines bring petroleum products into Colorado from refineries outside the State, and one pipeline (Wyco) brings refined products from Wyoming through Denver to a terminal at Fountain (just outside Colorado Springs). Table 4.2 shows the details of product pipeline movement into Colorado.

Gasoline and diesel fuel are distributed from refineries and pipeline terminals by tank truck to service stations. Colorado has over 3,300 of these stations, distributed roughly in accordance with the State population. In Colorado Springs, there are approximately 284 service stations selling gasoline and diesel fuel directly to the public.

4.1.2 Demand

In 1974, motorists in the Colorado Springs area used 120 million gallons of gasoline, while those in Canon City and Florence (both in the Fremont County host area) used 6.5 million gallons (Reference 17). In the State of Colorado, 1,408 million gallons of gasoline were consumed in 1974 and 110,700 million gallons were used nationwide (Reference 18). In terms of population and vehicles, Colorado's gasoline consumption represents 578 gallons per capita and 777 gallons per registered motor vehicle. Comparable figures for nationwide consumption were 528 gallons per capita and 881 gallons per registered motor vehicle. The use of diesel fuel for transportation is a relatively small and constant proportion of gasoline use. On a national basis, on-highway sales of diesel fuel, used primarily by large trucks and buses, amounted to 8.5 percent of gasoline gallonage while in Colorado, gallons of diesel fuel sold amounted to 6.5 percent of gasoline gallonage sold in the State (Reference 19).

4.1.3 Inventories

4.1.3.1 Risk Area Inventories.

To summarize the normal situation in the Colorado Springs area, petroleum product moves in about equal quantities either by pipeline or by tank truck from Denver to terminals in Colorado Springs. Storage tanks at the pipeline terminal have sufficient capacity to store about six days' normal demand for that half of the population receiving its gasoline from the pipeline. The other half of the population is serviced through secondary bulk terminals, with a total capacity equal to a four-day supply. From the pipeline and secondary storage terminals, gasoline and diesel products are distributed by tank truck and sold through about 284 gasoline stations in El Paso County. Inventories at the gasoline stations average about an eight-day supply, and the average automobile carries a 4.75-day supply. In Colorado Springs, then, there

TABLE 4.2: PETROLEUM PRODUCT PIPELINES INTO COLORADO

Name	Originates From	Colorado Terminals	Throughput Capacity (bbls./day)	Typical Mix	Estimated Storage Capacity (barrels)	Owners and Share
Wyco	Casper, Wyoming	Denver	38,000	50% gasoline 22% diesel 28% other	200,000	Texaco (40%) Amoco (40%) Mobil (20%)
		Colorado Springs (Fountain)	12,000	Same	100,000	
Medicine Bow	Sinclair, Wyoming	Denver	15,000	70% gasoline 30% mid-distillates		Pasco
Chase	El Dorado, Kansas	Denver	20,000 initial 80,000 eventual	74% gasoline 26% mid-distillates	500,000	Koch (50%) Skelly (50%)
Phillips-Shamrock	Borger, Texas	Denver	20,000	50% gasoline 40% mid-distillates 10% other	200,000	Phillips (80%) Shamrock (20%)
		La Junta	10,000	Same	100,000	

Source: Discussion with Denver FEA officials.

is an average inventory of 14 days' supply of motor fuel, measured against normal usage patterns. This inventory is located in automobiles, service stations, secondary bulk terminals, and the pipeline terminal, all points which are readily accessible under emergency conditions.

4.1.3.2 Host Area Inventories.

Secondary bulk terminals and gasoline stations within the Colorado Springs host area receive their fuel supplies entirely by truck. A survey of these terminals and stations reveals that the average bulk terminal has a storage capacity of 27,400 gallons of gasoline and 12,000 gallons of diesel fuel. The average host area service station has a storage capacity of 11,100 gallons of gasoline. The location of host area stations and bulk storage facilities has been charted by SYSTAN as part of earlier research to develop a prototype plan for evacuating the Colorado Springs risk area (Reference 6).

Measured in terms of normal fuel consumption rates, host area gasoline stations have an average of 8-1/4 days of inventory on hand. This assumes storage tanks are half-full on the average, and compares favorably with the average inventory of eight days computed for risk area gasoline stations. Secondary bulk terminals have an average of 4-3/4 days of gasoline on hand. This figure is higher than that computed for secondary storage in the risk area, and suggests that inventories in secondary terminals may increase as the distance from the source increases. The secondary storage capacity for diesel fuel available in the host area nearly equals that available in the risk area, and the number of diesel fuel pumps available in the host area is nearly ten times the number available for public use in the risk area. The greater availability of diesel fuel outlets in the host area reflects the greater use of diesel fuel in intercity trucking and the need for diesel fuel stops along major intercity routes. Furthermore, statistics on diesel fuel storage within the risk area do not include private storage tanks maintained by trucking companies, bus operators, and military installations.

4.2 FUEL REQUIREMENTS UNDER NORMAL AND CRISIS RELOCATION CONDITIONS

Fuel requirements before, during and after crisis relocation in both the risk and host areas of Colorado Springs are depicted in Exhibit 4.2. The total normal fuel consumption figures shown in this exhibit were developed in an earlier SYSTAN study (Reference 6) and reflect the actual recorded fuel consumption statistics for Colorado Springs risk and host areas in 1974. These total figures were divided into their component parts to provide a basis for assessing fuel requirements during and after relocation. The primary components of normal fuel consumption are personal and goods movement. Personal movement is further subdivided into work trips, family business trips, social and

recreational trips, and education trips. Goods movement is subdivided into two major categories: intercity trucking and local trucking.

Exhibit 4.2 shows that the total fuel requirements in the risk and host areas drop below normal daily requirements both during and after relocation. As may be expected, however, fuel requirements in the host area increase during and after relocation, while risk area fuel requirements drop markedly as relocation progresses. The estimates of fuel needs during and after relocation shown in Exhibit 4.2 reflect fairly pessimistic assumptions regarding the need for personal travel following relocation. These estimates may be lowered substantially by curtailing personal travel following relocation and introducing strict fuel conservation measures. The nature and impact of such measures are discussed at length in an earlier SYSTAN report (Reference 6).

Since the demand for motor fuel during and after relocation is not likely to exceed normal demand, the chief fuel problem under relocation conditions will be one of redirecting the flow of gasoline from risk areas to host areas so that supplies are available where they are needed and reserves may be built up in relatively invulnerable locations.

4.3 DAMAGE ASSESSMENT

There are three vulnerable fixed components in the petroleum processing and distribution system: refineries, pipelines, and storage tanks. The damage to each of these components is summarized in Exhibit 4.3 and discussed in the following paragraphs.

4.3.1 Refineries

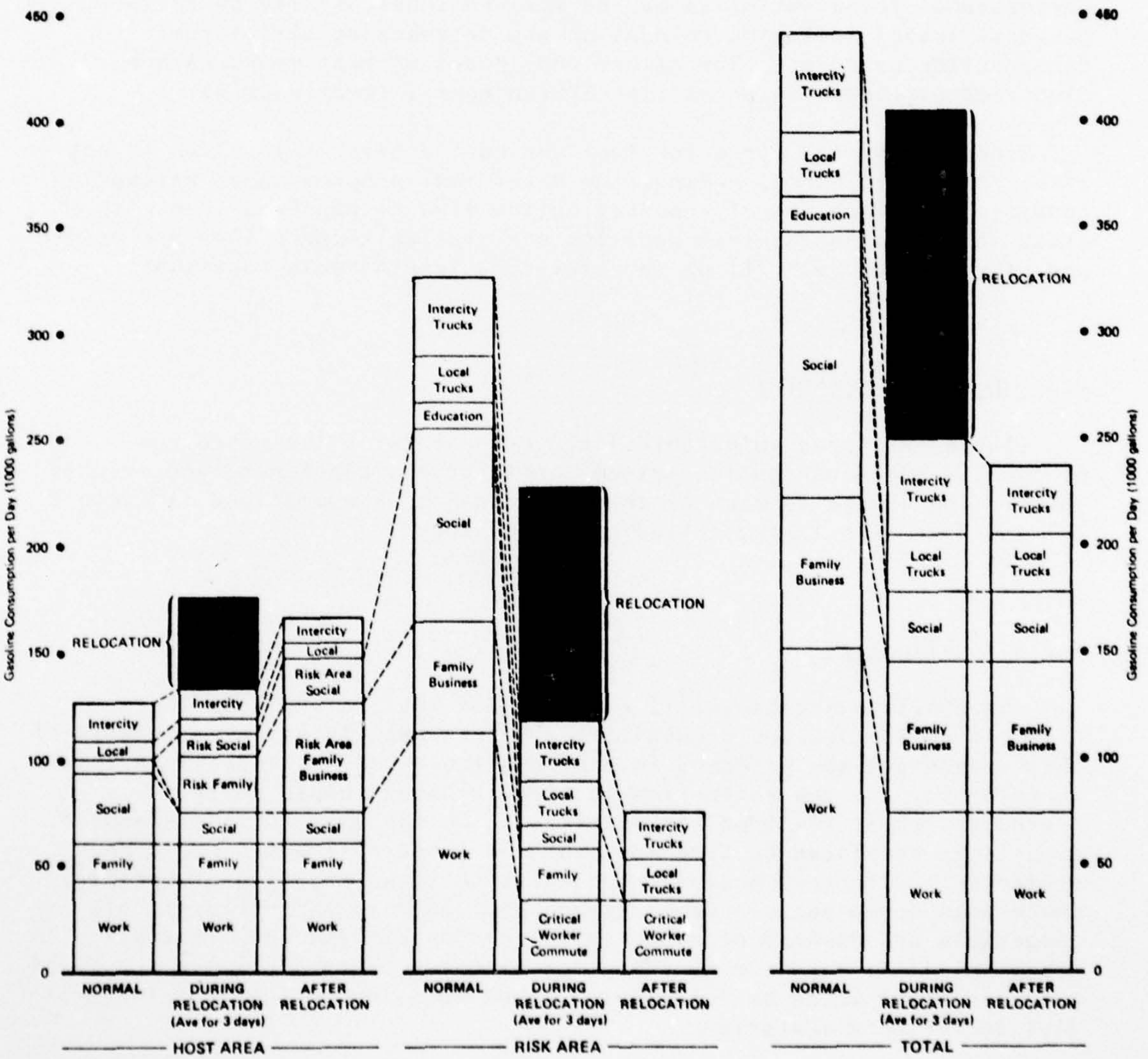
On a nationwide basis, it is estimated that only 31% of the nation's refineries would survive the UNCLEX-CHARLIE attack. Details of this assessment may be found in Appendix Table B-1. At the state level in Colorado, the two refineries located in Denver would sustain overpressures of 10-15 psi in an attack. On the basis of the analytic guidelines developed by Stephens, both of these refineries would be destroyed. Stephens' analysis indicates that the majority of refinery components would sustain major damage at 10.0 psi, and virtually all components are damaged or rendered inoperable at less than 15.0 psi. In addition, it is likely with this type of heavy damage that the supply of electric power would be interrupted, thus removing an input factor critical to refinery operation.

Stephens points out the interconnectedness of the damage to refineries:

> "The control house along with the water cooling systems, switch gear equipment and hydraulic lines are usually first to go. And once seriously damaged, the likelihood of plant operation in months is slim."

EXHIBIT 4.2

FUEL NEEDS BEFORE, DURING, AND AFTER RELOCATION



(Source: Reference 6)

EXHIBIT 4.3

SURVIVAL OF FUEL SUPPLY

AND DISTRIBUTION FACILITIES

	Nationwide Survival	Survival Within Colorado	Survival of All Colorado Sources
Refineries	31%	16%	60%
Bulk Storage	30%	39%	--
Pipelines	--	All Denver terminals destroyed; La Junta and Fountain terminals survive with slight damage.	Chase pipeline damaged at source; remaining pipelines escape damage at all points outside Colorado.

Even if a refinery is theoretically only one-third destroyed, if the crude distillation portion is the one-third that is destroyed, the entire plant is out of operation.

The Conoco and Refinery Corporation refineries in Denver have capacities of 30,000 and 20,500 barrels per day respectively; this refinery capacity would be lost in the postulated attack. The Gary Refinery near Grand Junction in Mesa County has a capacity of 9,500 barrels per day. This small refinery should remain undamaged, and could continue to function assuming crude were available.

4.3.2 Pipelines

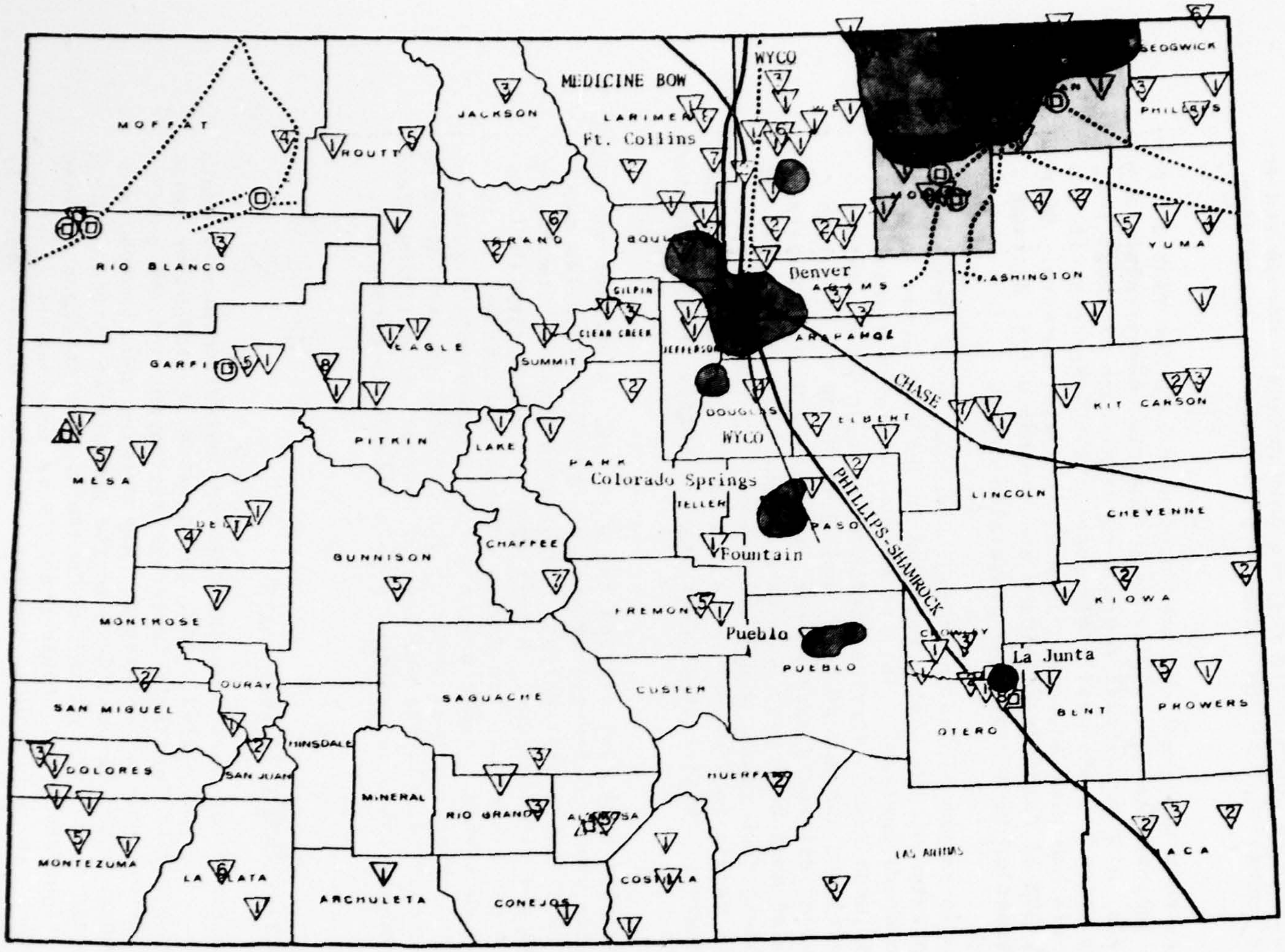
Pipelines are a critical part of the fuel supply system. Especially important are key pumping and compressor stations upon which the continuous operation of the oil and gas pipeline system depends. Pipelines underground should sustain little or no damage. Damage to pipeline facilities above-ground, however, can be compared to damage to certain components of a refinery. Pipeline instrumentation can be compared to refinery instrumentation. Damage to refinery controls occurs at 3.0 psi and the instrument cubicle is overturned or destroyed at 5 psi. Damage to above-ground pipes could occur at 3.5 to 6.5 psi. Pipeline operation requires electricity; debris missile damage occurs to transformers at 4.5 psi and power lines are severed at 7.5 psi. Central city power sources or distribution systems could also be out (Reference 16).

For this study, "moderate damage" was indicated for those pipeline installations where overpressures ranged between two and five psi and "light damage" was indicated for overpressures below 2 psi. As indicated above, controls in the instrument cubicle can be damaged at 3 psi. It is assumed this type of damage could be repaired in a relatively short time. Debris missile damage to electric motors could occur at 5 psi.

The Wyco pipeline facilitates south of Fountain should receive only light damage in the postulated attack, and it assumed to retain 100% capacity capability. The Phillips terminal of the Phillips-Shamrock east of La Junta should receive only moderate damage, and is assumed to be operational at 50% capacity within a reasonably short time after the postulated attack. Exhibit 4.4 shows blast and fallout areas in relation to Colorado refineries and pipeline systems.

4.3.3 Storage Tanks

Primary petroleum storage tanks are located at the pipeline terminals in Denver, Fountain (south of Colorado Springs), and La Junta (Otero County). The total capacity of these primary tanks is approxi-



- Blast Area
- Fallout Area
- Refinery
- Primary crude
- Crude Pipeline
- Product Pipeline
- Primary Products
- Secondary Storage
- Number of storage units

EXHIBIT 4.4

COLORADO PETROLEUM PRODUCTION AND DISTRIBUTION SYSTEM, SHOWING BLAST AND FALLOUT AREAS

mately 1,100,000 barrels (Table 4.2). The tanks in Denver would be destroyed by the postulated attack. The tanks at Fountain would receive only slight damage, and are assumed to retain 100% capacity capability, while the tanks at La Junta would receive only moderate damage and are assumed to be operational at 50% capacity soon after the postulated attack.

Secondary bulk storage tanks are located in both the risk and non-risk areas. Colorado secondary storage in the risk areas totals about 170,000 barrels, with an overall average survival rate of about 14%. Non-risk area secondary storage totals about 500,000 barrels; it is assumed that all non-risk area secondary storage will survive. Overall, approximately 39% of Colorado's primary and secondary fuel storage capacity is expected to survive the postulated attack.

Relative to volume of fuel consumed, secondary bulk storage capacity is much greater in the host areas than in the risk areas (e.g., Denver and Colorado Springs). This is because there is a greater proportion of large retail service stations in major urban centers. These large stations can accept full loads from 8,000-9,000 gallon tank-trucks which deliver directly from the primary bulk terminals. The storage tanks of most host area service stations are not large enough to accept full tank-truck loads, and therefore most are supplied from secondary bulk depots in the host areas. A few large stations in the host areas, however, receive tank-truck loads directly from the primary bulk terminals.

Blast resistance of fuel storage tanks is low. A nuclear air blast of a one megaton weapon detonated at optimum height 4-1/2 miles away would damage most tank installations. Ladders on tanks become flying missiles at 10 psi overpressure. A full tank is less susceptible to damage than an empty one but, for damage assessment purposes, it is generally assumed that all tanks are half-full. Tanks uplift between 3.5 and 6.5 psi. Floating roof tanks of the pontoon type can stand up to higher overpressure. Damage may result, however, from flying steel which may penetrate the side walls of even a relatively strong tank.

4.3.4 Summary of Damage to Facilities

It can be seen that damage to the Colorado petroleum supply would be substantial. The postulated attack would leave the two major refineries and four pipeline terminals in Denver destroyed, and the small refinery near Grand Junction undamaged. Key pumping and compressor stations in Denver would be destroyed in the postulated attack. The pipeline terminal (tanks and pumps) at Fountain, near Colorado Springs, would sustain light damage and could probably be functioning fairly soon after the attack. It is possible, however, that the Fountain terminal would be temporarily inoperative because of damage to the Wyco pipeline in Denver and Colorado Springs.

As shown in Exhibit 4.3, although refinery, storage and pipeline facilities are hard-hit within Colorado, survival of all Colorado sources is 60%. The Chase pipeline is damaged at its source in Kansas, but the remaining pipelines escape damage at all points outside Colorado. Table 4.3 shows possible immediate postattack fuel supply sources, assuming damaged pipeline terminals are bypassed with trucks. Although 60% of all Colorado fuel sources will survive the attack, this does not mean Colorado will receive 60% of its normal supply. As noted above, U.S. refinery survival, based on the UNCLEX-Charlie attack, is approximately 30%. Federal regulations (as set forth in the Federal Energy Guidelines, Reference 29) require that all states be treated equally in times of crisis. For planning purposes, therefore, it should be assumed that federal allocation procedures will limit Colorado's postattack fuel supplies to 30% of the state's preattack supply, the national average.

4.4 FUEL SUPPLY AND REQUIREMENTS UNDER POSTATTACK CONDITIONS

In the immediate postattack period, it is likely that there will be a serious shortage of fuel, with a supply at the national level and local levels of approximately 30% of the preattack average. Severe shortages will require appropriately strict controls, including impoundment of relocatee automobiles. Some restriction of cargo shipments may be necessary, but there should be sufficient fuel for the shipment of food and other essential items.

Since much of the nation's ordinary consumption of motor fuel is non-essential and could be eliminated by strict controls in time of emergency, the survival of 30% of the supply system should be adequate to meet essential needs. It is impossible to compute the precise demand for fuel following an attack without a nationwide model of commodity movement such as that discussed earlier in this report. Moreover, reconstruction activities during the postattack period will place demands on the transportation system that do not resemble peacetime demand patterns. Nonetheless, it may be instructive to consider the surviving inventories in the Colorado Springs host area in the light of the normal gasoline consumption levels for both risk and host areas. Table 4.4 summarizes transportation fuel requirements for the Colorado Springs risk and host areas before, during and after crisis relocation. This table shows that, if personal vehicles are impounded following relocation and the critical work force commuting to the risk area is limited to 8% of the normal work force, fuel requirements for the Colorado Springs risk and host areas could be reduced to 161,200 gallons per day, or roughly 36% of normal usage.

The retail gasoline stations and secondary bulk storage tanks in the Colorado Springs host area have a capacity for 4.5 million gallons of gasoline and 1.0 million gallons of diesel fuel, or 5.5 million gallons of motor fuel. Assuming these tanks to be half-full on the average, then, 2.75 million gallons of fuel would be expected to survive an attack occurring just after an evacuation has been completed. This

TABLE 4.3

POSSIBLE IMMEDIATE POSTATTACK FUEL SUPPLY SOURCES, ASSUMING DAMAGED PIPELINE TERMINALS ARE BYPASSED WITH TRUCKS

Facility	Capacity Barrels/Day	Supply Available in the Immediate Postattack Period (by Truck) Barrels/Day
Refineries		
Conoco Refinery, Denver	30,000	0
Refinery Corporation, Denver	20,500	0
Gary Western, Denver	9,500	9,500
Pipelines		
Wyco (Casper, Wyoming-Denver)	38,000	38,000
(Colorado Springs)	12,000	12,000
Medicine Bow (Sinclair, Wyoming-Denver)	15,000	15,000
Chase (El Dorado, Kansas-Denver)	20,000	0
Phillips-Shamrock (Borger, Texas-Denver)	20,000	20,000
(La Junta)	10,000	10,000
Total	175,000	104,500*

*The total of 104,500 barrels per day represents approximately 60% of "normal" capacity; however, all states would share surviving supplies equally, and therefore (based on the UNCLEX-CHARLIE attack) would be allowed 30% of its preattack supply.

TABLE 4.4

COLORADO SPRINGS RISK AND HOST AREAS

MOTOR FUEL REQUIREMENTS BEFORE,

DURING AND AFTER CRISIS RELOCATION

Usage Category	Thousands of Gallons Per Day		
	Before Relocation	During Relocation	After Relocation
Cargo Trucks	84.38	71.90	59.45
Intercity	55.69	44.55	33.41
Local	28.69	27.35	26.04
Personal Transport	368.90	101.75	101.75
Work	154.20	54.33	54.33
Family Business	71.56	29.72	29.72
Social and Recreational	125.79	17.70	17.70
Education	17.34	0	0
Personal Relocation	---	151.88	---
TOTAL	453.28	325.33	161.20

(Figures assume impoundment of personal vehicles following relocation and a critical risk area workforce of 8 percent of normal manpower.)

supply would be immediately accessible to survivors, even if all incoming pipelines were damaged and refineries outside Colorado were slow in recovering from the attack. Measured against post-relocation usage rates of 161,200 gallons per day, this surviving fuel supply could be expected to last seventeen days. Assuming that an attack occurs some time after the relocation has been completed, surviving fuel supplies in the host area would be proportionately greater, as the time following relocation could be used to stockpile fuel in relatively invulnerable locations (see Section 5.4).

Reconstruction of refineries and other segments of the petroleum processing and distribution network will require significant concentrations of time, manpower and materials. Even moderate damage to a refinery could take one year or more to repair, depending upon the section of the refinery receiving damage and the availability of materials. Appendix Tables D-1 and B-3 identify the blast overpressures sustained by primary petroleum facilities in Colorado and list repair requirements by refinery type in terms of man-days. In view of the importance of motor fuel to the economy and the prospect of severe fuel shortages during the immediate postattack period, reconstruction of key elements of the fuel supply and distribution network should be accorded high priority following a nuclear attack.

4.5 IDENTIFICATION OF ALTERNATIVES

This section identifies and explores alternative strategies for obtaining motor fuel and controlling its distribution in the Colorado Springs area following a nuclear attack. Strategies are classified into the following five categories:

1. Supply and distribution system adjustments designed to bypass damaged facilities and supplies to surviving host area storage facilities and gasoline stations.

2. Fuel conservation measures designed to reduce unnecessary fuel consumption following an attack. Such measures include the impounding of private automobiles and increased reliance upon buses and carpools for essential travel.

3. Stockpiling measures designed to increase the supply of fuel reserves in the host areas during the preattack period.

4. Fuel rationing measures designed to control fuel distribution at the gasoline pump.

5. Product integration measures designed to speed the distribution process and simplify adjustment procedures. Examples of such measures include the encouragement of intercompany fuel transfers, elimination of product separation, and the unrestricted use of leaded gasoline.

4.5.1 Supply and Distribution System Adjustments

As noted above, Colorado's refinery, primary storage, and pipeline system would be significantly damaged by a nuclear attack. The two Denver refineries and four pipeline terminals would be destroyed, the pipeline terminals at La Junta seriously damaged, and the Wyco terminal at Fountain would sustain light to moderate damage. All of these facilities except the Grand Junction refinery would be out of operation in the immediate postattack period.

However, certain of the pipelines could be tapped outside the State at such points as Casper and Sinclair, Wyoming and Borger, Texas. (El Dorado, Kansas, the origin of the Chase Pipeline, however, is in a high-risk area and would be heavily damaged by the blast.) These points outside the State, which include product storage facilities, can be used as the supply points for Colorado immediately after the attack. Trucks can take the place of the damaged pipelines and deliver fuel to the host area secondary storage facilities and service stations. Calculations indicate that the strategy of bypassing damaged pipelines with tank-trucks would increase the normal distance traveled by Colorado trucks in distributing fuel by a factor of 41% (see Section 3.2).

4.5.2 Conservation Measures

Several fuel conservation measures were evaluated and discussed in detail in the SYSTAN study Impacts of the Crisis Relocation Strategy on Transportation Systems (Reference 6). Some of these measures are also applicable to the postattack period, when serious fuel shortages may threaten to cripple not only non-essential travel but critical trips as well. Three of these measures are:

1. Limiting use of relocatees' automobiles by impoundment or by a pass system;

2. Using buses and carpools to transport critical workers; and

3. Greater use of buses for all transportation.

In addition to these measures, many of the measures identified in Chapter 2 to improve vehicle utilization would also serve to improve fuel efficiency.

4.5.2.1 Limiting the Use of Relocatee Automobiles.

Limiting the use of relocatees' automobiles has been discussed in detail in Impacts of the Crisis Relocation Strategy on Transportation Systems. Although these alternatives were meant to be applied to a crisis relocation situation, they are also applicable to the postattack period. During the crisis relocation period, relocatees' automobiles

will have been impounded. Thus, in the immediate postattack period, all or a portion of these cars can continue to be held in an impoundment status. It is during the first 30 days after the attack when fuel supplies are expected to be most critical. The maintaining of a restricted-use status for autos at the crisis relocation level would result in fuel savings of 42% compared with precrisis "normal" conditions (Reference 6). As emergency pipeline terminals are built and other necessary supply measures taken to ease the fuel supply situation, autos could gradually be released from restricted-use status.

Stringent vehicle controls such as impoundment would eliminate all non-critical travel. Less stringent measures entailing the use of temporary passes could also result in significant fuel savings. Also, controls on use of automobiles could serve as a means of preventing unauthorized entry to dangerous fallout areas.

4.5.2.2 Use of Buses Whenever Possible.

The use of buses as a fuel conservation measure during and after relocation has been covered in detail in Reference 6. The increased use of buses for work and other travel during the postattack period may result in fuel savings and provide an additional measure of control over access to restricted areas. One bus carrying 25 passengers at 5.5 miles per gallon is 3.67 times as energy-efficient as one car carrying three passengers at 12.5 miles per gallon. During the postattack period, critical workers may be entering fallout areas for limited periods of time, and buses could be useful in this transportation, particularly if the drivers are trained in fallout detection and protection measures.

4.5.3 Preattack Stockpiling

The spector of potential fuel shortages following a nuclear attack increases the importance of stockpiling fuel in relatively invulnerable locations during the preattack period. Stockpiling is a particularly attractive option following a crisis relocation, when the nation's fuel production capability is expected to exceed consumption levels by a significant amount. To the extent possible, any excess fuel produced during or after a relocation effort should be stockpiled in bulk storage facilities located in host areas. In the event that the period of crisis extends long enough to permit these facilities to be filled, a number of alternative storage options should be explored. These include:

1. Filling the tanks of impounded automobiles;

2. Using underground storage;

3. Constructing new bulk storage facilities; and

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POSTATTACK IMPACTS OF THE CRISIS RELOCATION STRATEGY ON TRANSPO--ETC(U)

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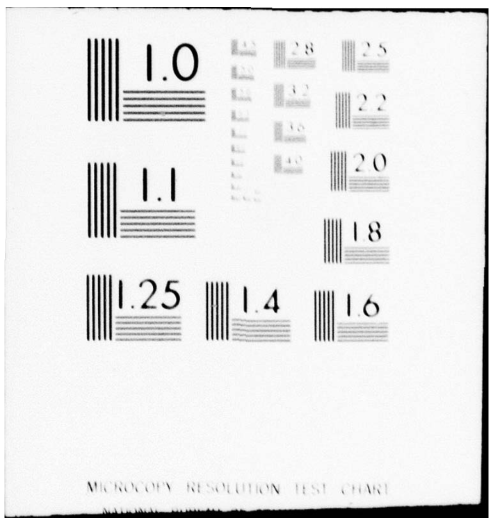
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MICROCOPY RESOLUTION TEST CHART

4. Building expedient storage facilities

The choice of alternatives will depend on immediate and projected needs in the postattack period. The tanks of impounded automobiles may provide immediate storage, while the construction of new bulk facilities would be incorporated in comprehensive postattack reconstruction schemes. Each of these alternatives is discussed in more detail in the subsequent chapter on activities during an extended crisis period (see Section 5.4).

4.5.4 Fuel Rationing

Various fuel rationing options, such as ration coupons, odd/even license plate controls, purchase limits and minimum tank requirements have been considered in an earlier study (Reference 6) as potential control measures under crisis relocation conditions. Although such measures are not strictly necessary during the relocation period, when fuel supplies are likely to exceed demand, they will certainly be required following a nuclear attack, when fuel will be in short supply. The need for strict rationing measures following an attack, coupled with the desire to stockpile as much fuel as possible prior to an attack, strengthens the argument for introducing strict rationing measures once the relocation is completed. In the immediate postattack period, rationing controls will be combined with even stricter measures, such as vehicle impoundment. Strict controls will also be needed in the immediate postattack period to ensure that only authorized personnel are able to obtain motor fuel. As the postattack supply of fuel increases and vehicles are gradually released from impoundment, rationing measures may be adjusted to reflect changing conditions.

4.5.5 Product Integration

Another general set of measures that might speed the distribution of fuel and simplify reallocation procedures entails the elimination of product distinctions. These distinctions might be broken down through a variety of measures designed to eliminate the separation of brands, and the segregation of regular and premium grades.

4.6 SUMMARY

An analysis of the damage to U.S. and Colorado petroleum production and distribution facilities indicates that a severe fuel shortage would probably follow a nuclear attack. The destruction of Colorado refineries, storage facilities and pipelines would necessitate changing patterns of distribution and strict fuel use controls.

Both the United States and Colorado rely heavily on outside sources for their petroleum supply. Present U.S. petroleum consumption rates are about 16 to 17 million barrels per day, and about half of this is imported. Colorado supplies only about 30% of its gasoline requirements from within the state; the remainder is imported from Kansas, Montana, Texas and Wyoming. At the local level, Colorado Springs must satisfy all its fuel needs by importing fuel from Denver, either by tank truck or pipeline.

In Colorado Springs, there is an average of 14 days' supply of motor fuel, measured against normal usage patterns. This inventory is located in automobiles, service stations, secondary bulk terminals, and the pipeline terminal.

Colorado is supplied fuel by three refineries within the State and four pipelines which bring petroleum products into Colorado from refineries outside the State. The largest two refineries are in Denver and would be destroyed by the postulated attack, while the third and smallest refinery located in Grand Junction would remain undamaged. Two pipelines -- Wyco and Medicine Bow -- bring products to Denver from Wyoming refineries, and the Wyco pipeline continues on through to supply Colorado Springs. The Denver terminals of these pipelines would be destroyed in the attack. The Wyco Colorado Springs terminal would sustain light damage, and could probably be functioning again fairly soon after the attack. The Chase product pipeline supplies Denver from refineries in El Dorado, Kansas; facilities at the supply points in Kansas, as well as the Chase pipeline terminal in Denver, would be destroyed in the postulated attack. The Denver terminal of the Phillips-Shamrock pipeline, which supplies products rom Texas, would also be destroyed, while the La Junta terminal would sustain light to moderate damage. In summary, Colorado petroleum facilities would be severely damaged, but up to 60% of the preattack fuel supply could still be transported by truck from the Wyoming and Texas supply points which remain undamaged. However, on the national level, only about 30% of U.S. refinery and storage capacity would survive the UNCLEX-Charlie attack; therefore, it is anticipated that federal reallocations would effectively cut Colorado's supply to 30% of the preattack level.

Several alternative methods of alleviating the fuel shortage in the postattack period have been identified. These include:

- <u>Assigning top priority to the repair of refineries and pipelines.</u>

- <u>Adjusting the fuel supply and distribution system to bypass damaged facilities.</u> In the immediate postattack period, trucks could be used to bypass damaged Denver refineries and pipelines and provide Colorado survivors with fuel from surviving supply points in Casper, Wyoming, Sinclair, Wyoming, and Borger, Texas. This adjustment would require a 41% increase in the mileage normally required to transport fuel to Colorado.

- <u>Introducing rigid control and conservation measures.</u> Such measures would include: (1) limiting cargo shipments to essential

goods; (2) moving critical workers in buses and carpools; (3) impounding personal automobiles; and (4) introducing strict fuel rationing measures.

- Stockpiling fuel in host areas prior to an attack. Following a relocation effort, the nation's fuel production capability is expected to exceed the demand for motor fuel. Excess production should be stockpiled in host area gasoline stations and bulk storage tanks. Once these reservoirs are filled, additional fuel might be stored underground, in expedient storage facilities, or in the tanks of impounded automobiles.

The available fuel supply will be the constraining element in the postattack management of the transportation system. In this regard, fuel shortages will be more critical than either vehicle losses or road damage. However, there should be sufficient fuel to support the movement of food and other essential commodities if its use is carefully controlled.

5. ANALYSIS OF EXTENDED CRISIS SITUATION

5.1 INTRODUCTION

If the initial crisis relocation is not followed by an attack or a cessation of hostilities, an extended relocation may result in which risk area residents reside for relatively long periods of time within the host area. In the event such an extended relocation period occurs, several adjustments might be made in the relocation posture. For example, the number of critical industries and commuting workers might be increased, while some non-critical activities may be transplanted from the risk to the host area and restarted for the duration of the extended relocation period. At the same time, stockpiles of critical commodities could be amassed in the host area. Such adjustments could have potentially large impacts on the transportation network and fuel supply system. As part of SYSTAN's investigation, a range of adjustments associated with an extended relocation period was postulated, the transportation impacts of these adjustments were quantified, and alternatives for providing transportation support throughout the extended period were proposed and evaluated.

In investigating the implications of an extended crisis period on the transportation system, several assumptions were made regarding the nature and extent of the activities to be initiated during an extended crisis period. These assumptions included:

1. Base Case: No changes in pre-planned risk area and host area activities which would affect food or transportation support. Workers commute to risk area for critical activities only.

2. Increased Risk Area Activity: The number of workers commuting to the risk area increases as additional risk area industries are reactivated.

3. Stockpile Creation: Food and fuel supplies are stockpiled in the host area to reduce the vulnerability of supplies and provide an immediately accessible source in the event of an attack.

4. Increased Host Area Activity: Selected risk area activities are transplanted in the host area.

Each of these assumptions is discussed in the following sections.

5.2 IMPLICATIONS OF INCREASED RISK AREA ACTIVITY

The basic assumption used in estimating risk area activity following relocation assumes that all necessary risk area activities would be continued. Using estimates by Strope (Reference 20), the continuation of necessary risk area activities[1] would require about 5% of the risk area labor force in Colorado Springs. In addition to the basic list of "necessary" organizations, Strope also identified organizations which could possibly continue to operate within the risk area during the CRP period. The number of risk area employees associated with these organizations represents about 5.4% of the total risk area labor force.

For purposes of estimating the population commuting to the risk area during the extended crisis period, three assumptions were examined: (1) It was assumed that critical workers included only the employees of "necessary" risk area organizations." (2) A second assumption increased the number of critical workers to include employees of both "necessary" and "possible" risk area industries, or 10.4% of the risk area labor force. (3) A third alternative assumed that critical workers represented 20% of the risk area labor force.

TABLE 5.1: NUMBER OF CRITICAL WORKERS IN RISK AREA

Assumption	Category	Employees Commuting to Risk Area: Number	Employees Commuting to Risk Area: % of Labor Force	Critical Workers in Risk Area at a Specific Time
1	Necessary Risk Area Operations	4,802	5.0	2,401
2	Necessary Risk Area Operations	4,802	5.0	
	and Possible Risk Area Operations	5,206	5.4	
	Total	10,008	10.4	5,004
3	Critical Workers Represent 20% of Risk Area Labor Force	19,389	20.0	9,695

Each of the above assumptions will have an impact on vehicle and fuel requirements during the extended crisis period. In an effort to assess

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[1]The names of organizations identified as necessary and the number of employees in each are listed in Table 1 of Appendix C.

the magnitude of that impact, vehicle mileage and fuel consumption estimates were made for each assumption.

5.2.1 Vehicle Mileage Estimates

5.2.1.1 Inventory Freight Movement.

In assessing the requirements for intercity freight movement under crisis relocation conditions, it was assumed that non-essential cargo shipments would be curtailed throughout the relocation period. In SYSTAN's earlier study of CRP transportation requirements (Reference 6), a list of essential commodities was compiled and the contribution of these commodities to intercity freight movement was estimated. A similar procedure was followed in assessing the impact of an extended crisis period in intercity freight movements. An additional list of commodities was compiled to reflect the output of those industries which were judged in earlier studies to be non-essential, but which could possibly be initiated under extended crisis conditions. An abbreviated listing of the major industries included in each classification appears in Exhibit 5.1.

Table 5.2 itemizes the intercity truck and rail mileage which will result (1) if shipments are restricted to essential goods, and (2) if the selected non-essential goods identified above are shipped under extended crisis conditions. In Colorado Springs, these situations correspond to risk area employment levels of 5% and 10.4% of normal, respectively. An estimate of the amount of intercity traffic produced by employing 20% of the risk area work force was made by extrapolating the results of the calculations made under assumptions (1) and (2).

5.2.1.2 Local Freight Movement.

An earlier SYSTAN analysis of data from eleven urban areas showed that slightly over half (50.8%) of the local truck trips on a typical day were made by trucks carrying essential products. If the number of products produced within the risk area were to be increased under extended crisis conditions, the number of local truck trips required daily would rise to an estimated 57.5% of normal. Table 5.3 lists the commodity categories included under both crisis and extended crisis conditions. Although the number of local truck trips would drop under conditions of crisis and extended crisis, the distance traveled on each trip would increase, since trucks will be required to move greater distances into the host area to distribute these goods. Within Colorado Springs, the distance traveled in local distribution movements was estimated to increase by a factor of 75%. This mileage increase reflects earlier estimates of the transportation stress imposed on the Colorado Springs food distribution system by the need to move supplies greater distances into the host area. The effect of this mileage increase is listed in Table 3 for conditions of crisis and extended crisis.

EXHIBIT 5.1

ESSENTIAL SHIPMENTS UNDER CRISIS RELOCATION CONDITIONS

AND ADDITIONAL SHIPMENTS UNDER AN EXTENDED CRISIS

Essential Shipments Under Crisis Relocation Conditions	Possible Shipments Under Extended Crisis Relocation Conditions
o Food and all products related to the production of food; o Products consumed by energy-producing industries; o Pulp and paper mills and selected paper products o Chemicals, pharmaceutical preparations, biological products, medical chemicals and botanical products, soaps and detergents, fertilizers, agricultural pesticides and chemicals. o Tires and inner tubes, rubber and plastic hosing and belting o Glass containers; o Basic steel and steel pipe; o Selected hand tools; o Farm machinery and equipment, construction machinery and equipment, selected power tools; o Health supplies and equipment; and o Products required by transport facilities, communications facilities, energy transmission and distribution facilities.	o Primary non-ferrous metal products o Fabricated metal products* o Industrial and other machinery** o Communications products and parts o Electrical products and parts * Metal cans are included in essential shipments ** Electrical machinery is included in essential shipments

TABLE 5.2

SUMMARY OF TRUCK AND RAIL INTERCITY SHIPMENTS, 1967

(IN TONS AND TON-MILES)

CATEGORY	Ton-Miles (Millions)			
	Motor Carrier	Private Truck	Total Truck	Rail
Normal Conditions	99,696	28,997	128,693	250,126
Crisis Conditions (all essential industrial plants operating)	63,126	16,782	79,908	102,561
Extended Crisis Conditions (all essential and selected unessential industrial plants operating)	72,057	18,467	90,524	112,324
Risk Area Employment at 20% of Normal	80,301	20,022	100,323	121,336
PERCENTAGE SHARE OF NORMAL CONDITIONS				
Normal Conditions	100.0%	100.0%	100.0%	100.0%
Crisis Conditions (all essential industrial plants operating)	63.3%	57.9%	62.1%	41.0%
Extended Crisis Conditions (all essential and selected unessential industrial plants operating)	72.3%	63.7%	70.3%	44.9%
Risk Area Employment at 20% of Normal	80.6%	69.1%	78.0%	48.5%

Sources: Census of Transportation, 1967 Commodity Transportation Survey, U.S. Bureau of the Census, Washington, D.C., Pages 1-105; and SYSTAN Analysis.

TABLE 5.3

PERCENTAGE DISTRIBUTION OF LOCAL TRUCK TRIPS PER DAY BY COMMODITY AND TRUCK CLASS IN URBAN AREAS (% OF NORMAL ACTIVITY)

Commodity Class	Normal Conditions		Crisis Conditions		Extended Crisis Conditions		20% Risk Area Employment	
	Total Trips	Col.Sprngs. Total Truck Miles	Total Trips	Col.Sprngs. Total Truck Miles	Total Trips	Col.Sprngs. Total Truck Miles	Total Trips	Col.Sprngs. Total Truck Miles
Products								
Food and Farm Products	28.2	28.2	28.2	49.4	28.2	49.4	28.2	49.4
Pulp and Paper Products	1.7	1.7	1.7	3.0	1.7	3.0	1.7	3.0
Chemicals, Petroleum, Coal	4.6	4.6	4.6	8.1	4.6	8.1	4.6	8.1
Manufactured Items	15.1	15.1	0	0	5.3	9.3	7.4	13.0
Scrap and Waste	3.5	3.5	3.5	6.1	3.5	6.1	3.5	6.1
Subtotal	53.1	53.1	38.0	66.6	43.3	75.9	45.4	79.6
Tools, Equipment, Misc.	22.7	22.7	6.8	11.9	7.9	13.8	9.7	17.0
Empty	24.2	24.2	6.0	10.5	6.3	11.0	7.3	12.8
ALL COMMODITIES	100.0	100.0	50.8	89.0	57.5	100.7	62.4	109.4

(Sources: Motor Trucks in the Metropolis, Wilbur Smith & Associates, New Haven, Connecticut, under commission from the Automobile Manufacturers Association, August 1969, pages 42 and 184; and SYSTAN analysis.)

Table 5.3 indicates that under extended crisis conditions in which additional risk area activity is contemplated, the vehicle mileage required for local truck deliveries will equal or exceed the mileage traveled by all trucks under normal conditions. In order to meet the local delivery requirements imposed by the extended crisis situation, trucks and drivers ordinarily employed in the distribution of non-essential goods and services will have to be employed in the delivery of such essential commodities as food and fuel. Past SYSTAN studies (Reference 6) have indicated that the existing local distribution system can support a doubling of normal vehicle mileage for short periods without requiring additional equipment from outside the local area. However, careful management of locally available vehicles will be needed to dedicate all trucks to the delivery of essential items, schedule drivers to maximize vehicle productivity, and introduce other measures designed to make the most of existing transportation resources. (See Section 2.5.2 for an example of such measures.)

The delivery of local goods appears to impose the most serious strain on the supply of vehicles and drivers under extended crisis conditions. The vehicle requirements for intercity travel will be well below normal, and the supply of automobiles and buses within the host area should be more than ample to meet the needs of the relatively small sector of the work force commuting to the risk area.

5.2.2 Fuel Requirements

Fuel requirements before, during and after crisis relocation in the risk and host areas of Colorado Springs are estimated in Table 5.4. These estimates, which are based on vehicle mileage projections for both personal and cargo movement, reflect the different assumed levels of activity once the evacuation is completed. Even under the most ambitious level of risk area activity anticipated under extended crisis conditions, fuel requirements fall well below the normal demands experienced prior to the initiation of crisis conditions. Depending on the degree of risk area activity continued following the completion of the crisis relocation, the fuel requirements depicted in Table 5.4 represent from 35% to 40% of normal daily requirements.

Comparisons of post-relocation supply and demand estimates, coupled with interviews with oil industry officials and FEA representatives, lead to the conclusion that existing host area bulk terminals and service stations will be adequate for the task of meeting fuel needs during and after relocation. Assuming normal production rates are maintained during and after relocation, a significant fuel surplus will build up during any period of extended crisis conditions. The possibility of stockpiling this surplus against a potential attack is explored in the following section.

TABLE 5.4

COLORADO SPRINGS - RISK AND HOST AREA
FUEL REQUIREMENTS UNDER EXTENDED CRISIS CONDITIONS
(Gallons/Day)

			AFTER RELOCATION		
Fuel Usage Category	BEFORE RELOCATION	DURING RELOCATION	5% WORK FORCE COMMUTING	10.4% WORK FORCE COMMUTING	20% WORK FORCE COMMUTING
Cargo Trucks	84.38	72.25	60.11	68.07	74.83
Intercity	55.69	45.14	34.58	39.15	43.44
Local	28.69	27.11	25.53	28.92	31.39
Personal Transport	368.90	96.94	96.94	105.60	120.77
Work	154.20	49.52	49.52	58.18	73.55
Family Business	71.56	29.72	29.72	29.72	29.72
Social & Recreation	125.79	17.70	17.70	17.70	17.70
Education	17.34	0	0	0	0
Personal Relocation	--	151.88	--	--	--
TOTAL:	453.28	321.07	157.05	173.67	195.80

5.3 IMPLICATIONS OF INCREASED HOST AREA ACTIVITY

The impact of increased risk area activity on the transportation system have been discussed above. It is also possible, however, that certain activities can be transported from the risk area to the host area and restarted for the duration of the extended relocation period. It appears that the net effect of such moving of activities is reduction of transportation distances and hence transportation requirements. There should be enough fuel and vehicles to support any technically feasible alternative.

Activities which could be moved from the risk to the host area include:

1. Wholesale Food Warehousing;

2. Certain Food Processing Activities;

3. Vehicle Maintenance Centers; and

4. Railyard Activities.

In addition, certain activities peculiar to the crisis circumstances would be introduced in the host areas. These include:

1. Shelter Construction;

2. Hardening of Key Industrial Facilities; and

3. Construction of Fuel Storage Facilities.

Each of these options is discussed briefly in the following sections.

5.3.1 Relocation of Wholesale Activities

During the time required to evacuate risk areas and for roughly one week following the evacuation, a number of factors favor a food distribution strategy in which the distributors continue to operate risk-area warehouses. The alternative of maintaining wholesale operations within risk areas is favored by industry officials and has several attractive features: The altered system is conceptually simple, and builds intelligently on the existing system without creating new operating entities. Corporate chains are preserved as distribution limits, and most host area retail stores will continue to be supplied by their pre-evacuation sources. Strain on the national distribution system is minimized, and supplies on the road from national processors and regional and local wholesalers at the time of the evacuation need not be rerouted.

As discussed in past SYSTAN analyses (References 9 and 30), an alternative to the continued use of risk-area warehouses entails the establishment of emergency warehouses and break-bulk centers within the

host area. This option has the advantage of decreasing the vulnerability of wholesale food supplies to attack, with the accompanying disadvantages of operating inefficiencies, system disruption, and delays in reestablishing normal operations in the event that no attack occurs. In addition, it is often difficult to locate suitable structures within the host area, and previous research has determined that new construction would require at least three weeks. One significant argument against the use of host-area warehouse space is the length of time required to empty existing risk-area warehouses. Food industry personnel estimated that they would require a minimum of four days to a maximum of two weeks to empty existing warehouses using current personnel and equipment. The average estimated emptying time was one week. Since the risk area warehouses will be operating throughout most of the expected duration of a crisis relocation, whether or not they supply retail outlets or emergency wholesale warehouses within the host area, they may as well function in their normal mode as a supplier of retail outlets. This will eliminate an extra, inefficient step in the distribution process.

In the event that the crisis relocation period extends beyond the three days required for relocation, food distributors will have filled host area retail outlets and mass feeding centers, and can consider the possibility of redirecting supplies to suitable host area warehouses. The desirability of relocating large-scale warehousing activities would, of course, would upon the availability of host area space which would be suitable or could readily be made suitable for food warehousing. In Colorado, for example, Fort Collins in Larimer County has several relatively large warehouses which are suitable for food warehousing and distribution. Most medium-sized cities have some space suitable for food warehousing which could be converted or commandeered. The adequacy of such space for total food warehousing requirements will vary considerably from one host area to another, and should be addressed in specific crisis relocation plans.

5.3.2 Expansion or Reactivation of Certain Host Area Food-Processing Facilities

Certain host area food-processing facilities could be reactivated or expanded after relocation. The milk processing field, for example, includes a number of small milk processing plants in rural areas that have gone out of business, giving way to larger, more efficient plants in more urban areas. Some of these host area plants could be reactivated to help supply the increased host area population and thus reduce milk transport distances. Also, in the meat packing field, small- and medium-sized host area packing plants can often increase output by three, four or more times through the addition of portable or fixed refrigeration capacity. The result is a decrease in transport requirements during the extended crisis period. In addition, reactivation of these facilities during the extended crisis period, when equipment and supplies can readily be transported from the risk area, will greatly enhance the production capability in the immediate postattack period in the event that the crisis ends in a nuclear exchange.

5.3.3 Expand Vehicle Repair Capability

Expansion of vehicle maintenance and repair capability usually means additional personnel and parts rather than new construction. Parts inventories can initially be built up from risk area supplies and subsequently (via direct shipment) from regional distribution centers. Vehicles requiring repair would be in host areas in case of attack; also, personnel would be in the host area and the number of commuting personnel would be reduced.

5.3.4 Transfer of Railyard Activities

The desirability of transferring certain railyard activities to the host area during a period of crisis relocation has been discussed in Section 3.4.

5.3.5 Other Activities

Other activities which would be introduced in the host area under crisis relocation conditions include:

1. Shelter construction;

2. Hardening of key facilities; and

3. Food and fuel stockpiling.

Shelter construction would use heavy earth-moving equipment to the extent that it is available in the host area, but there should be ample fuel in the host area to accommodate this activity. The hardening of key facilities is not expected to create excessive demands on the transportation network. In fact, postattack fuel distribution will be considerably improved if key pipeline terminals and refineries can be effectively hardened during the preattack period. Priorities for hardening key facilities should be worked out as part of a region's crisis relocation plans, and should reflect the damage likely to result from the anticipated attack pattern. In the Colorado Springs area, for example, hardening the pipeline terminals at Fountain and La Junta, which are on the fringes of the blast area, could leave these terminals damage-free following an attack. By way of contrast, no amount of hardening may be able to protect certain of the Denver refineries and terminals located near ground zero.

Certain stockpiling activities can be expected to have a more measureable impact on the transportation network during an extended crisis period. Fuel and food stockpiling options are discussed in the following section.

5.4 STOCKPILING ALTERNATIVES

In view of the potential fuel shortages and short-term food problems identified in the postattack analysis (see Section 4 and Reference 6), an extended crisis period presents an opportunity for stockpiling critical items such as fuel and food, which are likely to be in short supply following an attack. This subsection discusses several alternatives for creating stockpiles of critical commodities in host areas.

5.4.1 Fuel Supplies

Following evacuation, tank truck deliveries to all host area stations will be increased both to meet the increased fuel needs of the host area and to decrease the vulnerability of the nation's fuel supply. Since supply will exceed demand if normal production rates are maintained, an extended period of relocation could result in the development of critical fuel stockpiles in host area bulk terminals and gasoline stations. Assuming normal production rates are maintained during and after relocation, estimates of the post-relocation demand for fuel developed under alternative assumptions of risk area activity (see Table 5.4) indicate that motor fuel supply will exceed demand within the Colorado Springs area by between 260,000 and 300,000 gallons per day following relocation. If this excess were transported to secondary bulk storage terminals and gasoline stations within the host area, these bulk storage facilities would be filled within 2.4 days following the completion of relocation, and storage tanks in host area gasoline stations would require and additional 5-1/2 to 6 days to fill completely.[2]

Thus, if pre-evacuation production rates are continued, existing fuel storage capacity in the Colorado Springs host area will be exceeded in a little more than one week following crisis relocation, even under assumed conditions of relatively heavy risk area activity. A strategy of fuel stockpiling under extended crisis conditions will therefore require the creation of additional fuel storage capability in the host area. Possible alternatives for providing supplemental fuel storage facilities within the host area under extended crisis conditions include:

1. Filling the tanks of impounded automobiles;
2. Using underground storage;
3. Constructing new bulk storage terminals; and
4. Building expedient storage facilities.

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[2]This calculation assumes the tanks to be half-empty following the completion of relocation. A tabulation of fuel storage capacities in the Colorado Springs host area appears in Appendix C.

Each of these alternatives is discussed briefly below.

5.4.1.1 Tanks of Impounded Automobiles.

Among the most readily available sources of storage for the excess fuel produced during an extended crisis period are the gasoline tanks of the automobiles used in the relocation itself. The bulk of these automobiles would be impounded following the relocation, and could be refilled from host area outlets in the event of an extended crisis period. Automobiles could be released from impoundment on a scheduled basis during an extended crisis for the expressed purpose of refilling their fuel tanks, after which they would be reimpounded. This action would have the effect of freeing more fuel storage capacity within the host area and demonstrating to the automobile owners that fuel would be available for their use following the resolution of the crisis. Vehicles in use in the host area during an extended crisis should also be encouraged to "top off" their tanks frequently, keeping them as full as possible and freeing more fuel storage capacity within the host area.

In the case of Colorado Springs, an estimated 440,000 gallons of gasoline would be used by private automobiles carrying evacuees during the three-day relocation period. Assuming that the automobiles began their trips with full fuel tanks, and allowing for refills en route for cars traveling over 150 miles, calculations show that evacuating automobiles should arrive at their destinations needing roughly 220,000 gallons to refill all tanks. This empty-tank capacity represents slightly less than one day's excess production capacity under extended crisis relocation conditions, and refilling the impounded automobiles would free a corresponding amount of fuel storage capacity in host area gasoline stations and bulk storage facilities.

5.4.1.2 Underground Storage.

Underground storage is another possibility for petroleum product storage. Two European countries are known to store liquid petroleum products underground. In the United States (Colorado and elsewhere), natural gas is now stored underground, and investigations have been underway for some time on the storage of crude underground. Salt domes which occur in a number of states can be made suitable for this type of liquid storage.

5.4.1.3 Constructing New Bulk Storage Terminals.

It is unlikely that an extended crisis period will extend long enough to permit the construction of entirely new bulk storage facilities within the host area. Industry officials estimate that, by operating three shifts per day under emergency conditions, new bulk terminals could be constructed along pipelines outside the risk area within three

to six months, providing all materials were readily available. However, the stel for this type of facility is usually made to order, and can take from two months to one year or more to deliver, depending on other demands for steel. The cost of such construction is relatively high: A 100,000-barrel storage terminal, including the truck loading rack system, would cost 0.7 to 1.1 million dollars, and a 500,000-barrel facility would cost from 4.5 to 8 million dollars.

5.4.1.4 Expedient Storage.

One promising type of expedient storage facility suggested by industry officials entails the use of collapseable rubber-plastic containers. Such a storage facility has the advantage of requiring relatively short construction time.

This type of storage, referred to as "embankment support storage," has thus far been developed for crude or petroleum products up to a capacity of 25,000 barrels. It is essentially a 185' X 100' X 14' rubber-plastic treated fabric formed in the shape of a pillow, and supported on all sides by earth embankments. In collapsed form, a crated container can be delivered to a site on a semi-truck-trailer. Total construction time including earthwork, placement of container, roof and pumps and valves is about one week. Total cost is about $600,000 to $700,000 per 100,000 barrels of storage, or about two-thirds that of the permanent tank-type storage discussed above.

5.4.2 Food Supplies.

Research and discussions with industry and Department of Agriculture officials indicate that food supplies will be adequate to meet the needs of the relocated population during and after relocation. In the event of an attack, however, certain critical foodstuffs (meat, milk, wheat) would be in short supply during the first few weeks following the attack. Details of the shortages anticipated in the Colorado Springs area may be found in the SYSTAN report 'Effects of Attack on Food Distribution to the Relocated Population" (Reference 30). The possibility of stockpiling food to guard against potential postattack shortages is discussed below.

5.4.2.1 Meat and Meat Alternates.

It would be possible to increase production of canned meat and meat alternate products during and after relocation and to stockpile such production within the host area. National emergency standards for meat consumption are 70% of normal consumption levels, and part of fresh production could be diverted to production of preserved meat products not requiring refrigeration. Under normal conditions, however, only

about 10% of total meat products consumed are canned. In the case of Colorado, for example, total meat consumption is 456 million pounds per year, but only an estimated 46 million pounds of this is canned. Thus, even if canned production were doubled (this is considered the maximum feasible short-term increase), it would require 3.45 weeks of extra production to obtain enough canned storage for one week's emergency consumption.[3]

5.4.2.2 Milk and Dairy Products.

The U.S. Department of Agriculture (USDA) Agricultural Stabilization Service has about 385 million pounds of dried milk stored at approximately 200 sites around the United States. The fluid equivalent of this stored milk (3,465 million pounds fluid milk equivalent) would provide an emergency ration for the U.S. for a period of approximately 5.3 days.

In the case of Colorado, the quantity of milk presently stored in Denver (1.025 million pounds) would be sufficient for about 3.9 days of emergency rations for the State's total population.

Those USDA/ACS dried milk storage sites around the U.S. which are within risk areas should be identified and plans made to move such milk to new sites in the host areas during the crisis relocation period. Storage requirements for these emergency supplies are not highly restrictive, except that the storage locations should be clean and dry.

5.4.2.3 Cereal and Cereal Products.

Emergency consumption standards for cereal and cereal products are four pounds per week, assuming other foods are available. If grain is the main sustaining food, two pounds (3,000 calories) per day has been used as the quantity required for survival (Reference 21). The United States has consistently produced more grain annually than required. It is estimated that 30% to 40% of the annual U.S. grain production for each of the years from 1965 through 1975 would be adequate for the minimum annual survival quantity. Although figures indicate that an overall grain surplus exists, there are substantial variations in geographic distribution of grain stocks. Garland (Reference 21) indicates that the average food supply from grain stocks varied from approximately a two-day food supply in the New England states to approximately 34 years in North Dakota. In general, stocks are stored in the grain-producing areas, with other areas maintaining only working inventories. A study by Haaland (Reference 22) indicates that 46 million people in the United

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[3] 20% ÷ 70% = 29% of total emergency requirements would be canned, providing one week's consumption for each 3.45 weeks of production

States live in grain-poor areas where local grain stocks would supply less than five days worth of food under emergency conditions.

One attractive stockpiling option in an extended crisis period would entail the movement of stored grain from risk-area silos to grain-poor regions of the U.S. Both Garland (Reference 21) and Haaland (Reference 22) have computed the transportation requirements associated with massive movements of grain thoughout the U.S. Haaland has estimated the transport requirements for providing six weeks' supply of wheat to grain-deficit areas in the U.S. based on consumption levels of approximately two pounds of grain per person per day. He indicates that 1.2 million tons of wheat could be moved to grain-deficit areas in just under four weeks, while utilizing less than 2% of the 1970 rail capability and 1% of the 1970 trucking capability during that period. Working with comparable grain volumes, Garland (Reference 21) has analyzed regional grain requirements on a state-by-state basis. Garland's analysis also indicates that the U.S. transportation system could accommodate massive movements of grain during an extended preattack period.

Railroads would bear the brunt of any grain shipments during an extended crisis period. The railroads are equipped to carry grain in large quantities, and grain loading and unloading equipment exists throughout the grain-producing rural areas. On a ton-mile basis, railroads cost only about one-fifth as much as trucks and are about four times as fuel-efficient. Thus, rail is more suitable for longer hauls of bulk commodities. Trucks and barges, of course, would be essential for part of the work.

One problem in shipping grain to grain-poor host areas in an extended crisis period is that some of these areas have limited storage capacity. For example, Garland indicates that the rated off-farm grain storage capacity in the New England states on January 1, 1970 was only 4.1 million bushels. Garland suggests that one action which would help alleviate this situation is the development of federal incentive programs to encourage construction of commercial grain storage facilities. Conversion of ordinary warehouses to bulk storage facilities would also increase the wheat storage capability of grain-poor host areas. Wheat need not be stored in elevators; much of the wheat and other grains are presently stored in bulk in single-story warehouses. Many warehouse-type structures are suitable for bulk grain storage; provided the walls are of sufficient strength to withstand the lateral pressure. Even where warehouse walls are not strong enough, grain in sacks is often stacked along the walls to help support the bulk grain.

Under conditions of extended crisis, then, grain stocks should be moved from risk-area elevators to appropriate host-area storage facilities. Crisis relocation plans for risk areas should identify any significant stocks of grain which are at risk under threat of nuclear attack. At the same time, planners in host areas should identify any space which could be used for grain storage. State and regional plans should contain provisions for identifying movement patterns from risk-area terminals to host-area storage under extended crisis conditions.

5.5 SITUATION SUMMARY

In the event that an extended relocation period occurs, several adjustments might be made in the basic relocation posture. Three possibilities are: (1) the number of critical industries and commuting workers might be increased; (2) some critical or non-critical activities may be moved from the risk area to the host area; and (3) stockpiles of critical commodities could be built up in the host area.

Adjustments which would increase activity within the risk area place greater stress on the transportation system than does the basic crisis relocation situation in which workers commute to the risk area only for critical activities. In addition, the stockpiling of fuel and food during the extended crisis relocation period would add somewhat to the base case transportation requirements. Increased host area activity, however, would reduce transport distances and hence overall transport requirements.

An analysis of the extended crisis situation indicates that neither the base case nor any of the adjustments examined result in binding transportation or fuel support constraints. Moreover, since potential postattack shortages of fuel are anticipated, the stockpiling of fuel supplies within the host area is strongly recommended during any extended crisis period. Foodstuffs should also be stockpiled within the host area during a period of extended crisis, and an attempt should be made to expand the output of any food and fuel processing facilities located in the host area and to reactivate any recently closed food-processing plants.

6. IMPLICATIONS OF POSTATTACK RESEARCH ON PREATTACK CRP GUIDELINES

The results of the postattack research on the Colorado Springs study area have been reviewed in light of the current guidance for crisis relocation planning (Reference 6). As a result of this review, it appears that the basic strategy proposed for providing transportation under crisis relocation conditions is sound, although certain changes and additions are recommended. The analysis accompanying the damage assessment and evaluation procedures brought to light several elements which should be included in the crisis relocation guidance issued by the federal government and in the crisis relocation plans for specific areas. These elements include:

1. Provision for moving critical vehicles (such as switch engines and debris-removal equipment) out of risk areas where possible, and assembling parts inventories within the host areas;

2. Guidelines for identifying key host area railyards and planning for their expansion;

3. Guidelines for preparing a list of critical pipeline repair facilities and plans to protect them;

4. Provision for stockpiling fuel as soon as possible during crisis relocation, for constructing expedient bulk storage facilities within the host area, and for supporting plans for peacetime crude stockpiles and research into expedient storage structures and product storage; and

5. Provision for identifying key host- and risk-area truckstops, outlining the role of these truckstops under crisis relocation conditions, and forming a peacetime organization of truckstop owners.

6.1 MOVEMENT OF CRITICAL VEHICLES AND ASSEMBLY OF PARTS INVENTORIES

6.1.1 Movement of Critical Vehicles

Risk-area transportation plans should provide for the transfer of critical vehicles, such as switch engines and debris removal equipment, to appropriate host areas during the crisis relocation period. Due to their vulnerable concentration in railroad classification yards, switch engines are expected to have a lower survival rate than line-haul locomotives and freightcars. Switch engines and other power units will be urgently needed during the postattack period, and plans should therefore be made to move as many as possible out of the risk area during the latter part of the relocation period. Railroad debris-removal equipment should also be moved to the host area. In developing the Transportation Annex of risk-area plans, planners should review equipment inventories with rail personnel; determine how many of each category of equipment

should be moved; and arrange for the transfer of this equipment to appropriate host area locations. In addition, specialized motor vehicles such as ambulances, dump trucks, construction equipment, and debris-removal vehicles, should be moved to the host area during relocation to the extent that this is possible without disrupting risk area operations. Risk area planners should follow similar procedures in reviewing, locating, identifying, and arranging for the protection of these vehicles.

6.1.2 Assembly of Parts Inventories Within Host Areas

Locomotive spare parts and maintenance manuals should be moved to the host area during the crisis relocation period. Parts for trucks and other critical vehicles should be moved to the host area as well: Risk area planners should identify which types of items should be moved, locate them, estimate the quantities involved, and arrange for their transfer under crisis relocation conditions.

6.2 IDENTIFYING KEY HOST AREA RAILYARDS AND PLANNING FOR EXPANSION

The movement of critical rolling stock to the host area was discussed in Chapter 2 and summarized in Section 6.1. Possible host area locations to which this rolling stock can be moved during the crisis relocation period should be identified, and the estimated capacity and other relevant data on each potential site should be included in the planning process and made a part of the Transportation Annex. In general, railroad officials see no problem in finding space to set out critical rolling stock; most railroads have double track or sidings every few miles in order for trains to pass. Also, in time of emergency there would be no need to use only company-owned track. In fact, railroads normally have mutual agreements for the common use of track.

In addition to locating host area locations where critical rolling stock could be sited, key host area railroad terminals should be identified. The problem of loading and unloading freightcars could be very serious if main terminals are badly damaged or destroyed in an attack on urban centers. Therefore, key host area terminals should be identified and plans made for their expansion, including plans for provision of materials-handling equipment.

Discussions with railroad industry personnel will provide state and local planners with data on potential siting locations for rolling stock and on key host-area terminals suitable for expansion. In addition, such discussions will introduce railroad officials to civil defense thinking and provide these officials with some idea of what may be expected of them in the event of a crisis.

6.3 IDENTIFYING AND PROTECTING CRITICAL PIPELINE FACILITIES

Petroleum pipeline terminal facilities, including pumps, instrumentation, communications, and storage tanks, are critical links in the fuel supply system network and should be protected where possible. Where such facilities are located on the fringes of target areas, they would not be completely destroyed but would receive light to moderate damage. Even light damage could render these facilities inoperable in the first days and weeks after an attack when fuel will be critically needed. In many instances, such facilities can be relatively easily protected with sandbags, steel mesh, or earth embankments. Protection measures for petroleum facilities are discussed by Stephens (Reference 16). Discussions with petroleum industry officials will provide planners with data necessary to identify key pipeline facilities. Guidance for the protection of such facilities should be included in the Petroleum Annex, along with a set of priorities for protection reflecting both the importance of the facility and the anticipated level of damage at the site.

6.4 FUEL STOCKPILING

It is likely that there will be a critical shortage of fuel in the postattack period. Where possible, therefore, fuel should be stockpiled in the host area during the preattack period. Stockpiling activities should begin as soon as possible during crisis relocation.

6.4.1 Traditional and Expedient Storage Facilities

The first host area fuel storage facilities to be filled during the crisis relocation period would be such traditional facilities as secondary bulk terminals, gasoline station tanks, and the tanks of impounded automobiles. If the crisis remains unresolved for more than a week following the completion of relocation, however, the combined capacity of these facilities may be exceeded. Additional storage capacity would, in most areas, be quite useful; however, the construction of new traditional storage facilities would be costly and require several months to complete. Therefore, expedient storage may be more suitable for adding to host area fuel storage capacity. One promising type of expedient storage facility entails the use of collapseable rubber-plastic containers. This type of storage, referred to as "embankment support storage," has thus far been developed for crude or petroleum products up to a capacity of 25,000 barrels. In collapsed form, a crated container can be delivered to a site on a semi-truck-trailer. Total construction time is about one week. Total cost is about two-thirds that of the conventional permanent tank-type storage.

Continuing research on expedient storage facilities, such as the earth embankment type, should be encouraged. At present, research on the 25,000 barrel earth embankment type of expedient storage is being

conducted by the U.S. Army and rubber manufacturers. Several types of smaller collapseable rubberized fuel storage units, however, are presently being manufactured and are readily available.

Working with petroleum industry officials and regional and local Department of Energy officials, civil defense planners should prepare guidelines which include data on existing and potential risk and host area fuel storage facilities. Plans should include data on existing fuel storage locations, capacity, pumping rates, number of loading bays, the type of fuel which can be handled, as well as guidelines for the possible construction of expedient storage facilities.

6.4.2 Peacetime Crude Stockpiles

At present, about half of all crude refined and consumed in the U.S. comes from foreign sources. U.S. energy policy calls for increasing the quantity of crude stockpiled in the nation over the next several years. The primary sites for this planned build-up of crude storage are salt domes located mainly in the Gulf States region. Research on this project is continuing, and actual filling of the initial sites is underway. Present plans are to reach a level of one billion barrels by 1982. Civil defense representatives should support this stockpiling policy, and incorporate such stockpiles in postattack recovery plans.

6.5 IDENTIFYING AND EMPLOYING KEY HOST- AND RISK-AREA TRUCKSTOPS

The relative invulnerability of truckstops to nuclear attack, coupled with their importance in the day-to-day movement of intercity traffic, make them a pivotal resource in any crisis relocation plan. The role of truckstops in crisis relocation planning has been discussed in detail in Reference 13 and summarized in Chapter 3. Reference 13 provides basic data on 2,682 U.S. truckstops, including: name, address, telephone number, and brand of fuel sold. It also outlines the roles of risk area and host area truckstops under crisis relocation conditions. Using Reference 13 as a guide, planners should work with truckstop operators to prepare planning guidelines outlining the activities of local truckstops under crisis relocation conditions. Working with truckstop operators in the preparation of the guidelines will ensure that each operator is familiar with the possibilities and responsibilities of his role under emergency conditions. The peacetime formation of a nationwide association of truckstop operators organized for the purpose of providing emergency fuel and support would provide a focal point for such planning and contribute significantly to the nation's emergency preparedness posture.

6.6 SUMMARY OF PREATTACK IMPLICATIONS

A review of the implications of the indicated changes on preattack crisis relocation guidelines has resulted in the identification of several important measures which should be taken during the preattack period. One of these is planning for the transfer of critical vehicles, such as switch engines, debris removal equipment, and specialized motor vehicles, to the host area during the crisis relocation period. Plans should be made to move as many vehicles as possible without disrupting the orderly flow of necessary work. Locomotive spare parts and maintenance manuals, as well as parts for trucks and other critical vehicles, should be stockpiled in the host area during the crisis relocation period.

Provision should also be made for identifying key host area transportation terminals, such as truckstops and railyards, and planning for their use under crisis conditions.

Pipelines and pipeline terminals are critical elements in the fuel supply system network, and should be protected where possible. Relatively basic measures can provide protection against light or moderate damage which could render such facilities inoperable during the first days and weeks after an attack, when fuel will be critically needed. The identification of critical pipeline facilities and guidance and priorities for their protection should be included in the Petroleum Annex.

A critical fuel shortage during the postattack period is likely. Therefore, host area fuel stockpiling should be carried out as early as possible in the crisis relocation period. Storage capacity in the host areas is likely to be limited to secondary bulk storage, underground tanks in retail gasoline stations, and the fuel tanks of impounded automobiles. This storage capability could be augmented within one week by expedient storage facilities comprised of rubber-plastic containers. Local plans should include data on existing fuel storage locations, capacity, pumping rates, number of loading bays, and the type of fuel which can be handled, as well as guidance on potential storage facilities and possible construction of expedient storage. Postattack fuel shortages could also be alleviated through the use of crude currently being stored in salt domes underground as a hedge against future import embargos.

7. FIELD TESTS OF TRANSPORTATION PROTOTYPE PLANS AND PLANNING GUIDELINES

7.1 INTRODUCTION

During the final stages of the research, field tests were conducted in an attempt to validate the guidelines and plans contained in Volumes II and III of this report. These field tests took the form of interviews with planners and industry personnel designed to validate the approach and materials, and to elicit comments and data regarding the subject matter. Specific data from these interviews have been incorporated into the final versions of the case studies, planning guidelines, and prototype plans constituting the four volumes of this report. This chapter outlines the subject areas included in the field tests, the general approach to the respondents, a summary of the responses, and conclusions and recommendations.

The general objective of the field test program was to evaluate how well the prototype plans and planning guidelines met, at a minimum, the following criteria:

1. The guidelines should be understandable and usable by the DCPA regional, state and local personnel who will be developing plans for their own jurisdictions.

2. The plans themselves must make sense to the transportation industry officials whose job it will be to implement the plans under crisis relocation.

These dual criteria suggested that testing of plans and guidelines would require contact both with DCPA planners and with industry personnel. Accordingly, separate interview programs were undertaken at two levels:

1. The planning level (DCPA regional, state and local planners); and

2. The implementation level (transportation industry personnel).

7.2 VALIDATION AT THE PLANNING LEVEL

To validate the guidelines at the planning level, SYSTAN personnel interviewed selected DCPA regional, state and local personnel involved in nuclear civil protection planning to secure their views, inputs and recommendations on the developed guidelines. Interviews were conducted in three regions, selected jointly by DCPA and SYSTAN, to cover a representative range of planning experience, both geographically and functionally. The three regions were DCPA Region III (headquarters in Thomasville, Georgia), Region VI (headquarters in Denver, Colorado), and

Region VII (headquarters in Santa Rosa, California). A variety of state and local planners were present at these meetings, and each meeting was preceded by a series of telephone contacts eliciting information regarding the planners' experience with the guidelines.

7.2.1 Approach Overview

Most of the respondents were familiar with the earlier transportation planning guidance (Reference 6), and had working experience in applying that guidance to their particular problems. Generally, the roles of these individuals were known to the SYSTAN staff.

A variety of approaches were used in gathering information from DCPA planners. In most instances, individual telephone interviews were followed by an informal round-table discussion with the planners in the region. In one instance (Region VI), a formal presentation was delivered to a meeting of state DCPA representatives. Whatever the approach, the information sought was the same in all cases:

1. Description of the individual's role in crisis relocation planning;
2. Exploration of past experience with crisis relocation planning guidance and prototype materials;
3. Discussion of specific problems encountered in using guidance to develop crisis relocation plans;
4. Reaction to key elements of revised postattack guidance;
5. Discussion of impact of planning materials on respondent's activities;
6. Solicitation of additional data and suggestions for improvements; and
7. Derivation of conclusions regarding the materials.

7.2.2 Summary of Sample Planner Comments

The following list of comments summarizes the major reactions to the planning process in general, and transportation guidance in particular, elicited from DCPA planners during the review process. SYSTAN's observations on each comment are included in the list. Additional conclusions and recommendations appear in subsequent sections of this chapter.

GENERAL COMMENTS ON ALL DCPA CRP GUIDANCE

Planner Comment: The material provided is too detailed...There's too much for the planner to plow through and absorb.

Observation: This comment was the single observation heard most often, and was echoed by almost every planner interviewed. The planners' complaints appear justified to some extent. Perhaps DCPA should attempt to summarize guidance in a checklist format for use by local planners. However, the subject is a complex one and it is necessary for someone at the state and regional level to absorb and understand the detailed material.

Planner Comment: The organizational guidelines developed in the prototype plans for Colorado are not necessarily consistent with organizational set-ups in other states. Planners have trouble sorting out what is to be done at the regional level, what is to be done at the state level, and what is to be done at the local level.

Observation: Admittedly, organizational structures may vary from state to state, and the guidelines were developed by consultants who could bridge regional, state and local levels more easily than planners operating at one level or another. However, the prototype plans indicate what is generally expected at each level, so that planners should be able to sort out regional, state and local duties. The distinction between regional and state responsibilities may not always be clear-cut, but resolution of most conflicts should be possible at the regional level without holding up the planning process. Any attempts on the part of national DCPA headquarters to account for the organizational variety existing from state to state would increase the level of detail in the guidelines fifty-fold.

SPECIFIC COMMENTS ON TRANSPORTATION GUIDANCE

Planner Comment: We had trouble calculating transportation stress, and finally just used the graphs you provided in the guidelines.

Observation: Since the formulas for transportation stress proved confusing to several planners, worksheets have been added to the revised guidance to help planners compute transportation stress. The original graphs were intended as a simplified stress-analyzing technique, and they seem to have served that purpose well.

Planner Comment: Since food and other commodities will probably be transported in closed vans, cubic volume measures appear to be more appropriate for computing transportation requirements than weight measures.

Observation: This point is well taken. The revised food guidelines contain cubic volume conversion factors for the most common food commodities.

Planner Comment: The DCPA headquarters requirement that state plans be produced before local plans is backwards in the case of both food and transportation. It's difficult to develop reallocation plans at the state level before you know what needs to be moved at the local level.

Observation: This comment appears to be valid. One jurisdiction (Region VI) has resolved this conflict by addressing only organizational issues in the first draft of the state annex, with the intention of addressing substantive reallocation questions once local plans are well underway.

7.2.3 General Responses to Observations

Where possible, the comments of the planners have been reflected in these report materials. In many cases, however, the comments reflect the need for a tightening and summarizing of all guidance materials, which was beyond the scope of the current contract. A few observations regarding the overall guidance and prototype materials are listed below.

1. At all levels, the planners interviewed were conversant with the DCPA guidance and, for the most part, were using these materials as a basis for their planning activities.

2. Although the DCPA guidance materials, in their present form, appear to provide a generally acceptable and consistent basis for planning, they might be improved through the development of summary material highlighting key points and providing a checklist for planners to follow.

3. The wide range of background experience of the many individual planners, and the significant differences between geographical areas and levels of responsibility, limits the applicability of any single guidance document. Because it is not feasible to produce specific guidance to cover each situation, it is desirable provide interpretive sources. These may be supplementary written materials, oral briefings, or audio-visual materials.

4. Certain of the more detailed calculations required in the planning process proved confusing to several planners. Work-

sheets have been added to the revised guidance to help planners compute transportation stress, but more of these types of computation aids should be considered.

7.3 VALIDATION AT THE IMPLEMENTATION LEVEL

Final responsibility for implementing the transportation portions of the relocation plan under emergency conditions will rest with the members of the rail and trucking industries currently responsible for transporting essential commodities throughout the United States. To validate CRP plans at the implementation level, the planning guidance was discussed with a wide variety of industry representatives. Members of industry trade associations were interviewed, as were individual representatives of the rail and trucking industries. A sampling of truckstop operators was also contacted. The reactions of these industry representatives to the CRP plans and guidelines are summarized in Section 7.3.2. Where appropriate, their reactions have been incorporated in Volumes II, III and IV.

7.3.1 Subject Areas Covered

As appropriate to the respondent, the field interviews were structured to develop data and evaluate the guidance in terms of functional subject areas. These correspond to the major subdivisions of the planning guidelines:

A. Vehicles
- A.1 National and local inventories and usage;
- A.2 Requirements for CRP movement of people;
- A.3 Requirements for CRP movement of cargo; and
- A.4 Effects of probable postattack situation.

B. Road and Rail Network Capacity
- B.1 Sources of information;
- B.2 Planning guidelines and procedures; and
- B.3 Probable postattack situation summary.

C. Fuel for Transportation
- C.1 Overview of fuel transportation system;
- C.2 Fuel requirements;
- C.3 Motor fuel control and distribution;
- C.4 Preattack food stockpiling;
- C.5 Protecting critical industries; and
- C.6 Probable postattack situation summary.

In addition, field interviews were conducted on the special subject of the role of truckstops in crisis relocation. Pertinent subject areas included:

1. Overview of the truckstop network;

2. Inventory of U.S. truckstops;

3. Importance of truckstops in intercity cargo movement;

4. Potential role of truckstops in crisis relocation planning; and

5. Development of a nationwide emergency organization.

7.3.2 Summary of Responses of Industry Representatives

7.3.2.1 Rail Industry Personnel.

Representatives of the rail lines serving Colorado Springs, as well as rail industry personnel in the San Francisco Bay Area, were contacted before, during and after the prototype plans were drafted. Colorado Springs representatives identified suitable sidings in the host area for storing rolling stock and switch engines in time of crisis. In reviewing the draft guidelines, rail industry personnel suggested spotting flatcars loaded with preassembled rail panels at various host-area locations in order to facilitate postattack repairs. This suggestion has been incorporated in the planning guidance. The estimate that at least 30 days would be required to restore rail operations following an attack represents the consensus of the rail personnel interviewed.

7.3.2.2 Trucking Industry Representatives.

Representatives of the American Trucking Association (ATA), as well as individual truckers in Colorado and Northern California, were contacted in assembling estimates of the relative importance of truckstops in developing postattack plans and guidelines. The truckstop study led to the identification of major private fleets and fueling points, a proposed subject for future research. Proposed procedures for driver-dispatcher contact under emergency conditions were checked with trucking industry representatives, and members of the ATA in particular were enthused about the prospect of an emergency truckstop organization.

7.3.2.3 Truckstop Operators.

The report on truckstops (Volume III) was reviewed twice by Ed Slibeck of Union Oil and the National Transportation Fueling Corporation, and his comments have been incorporated in the final draft. Mr. Slibeck is one of the foremost authorities on truckstops in the United States. In addition, SYSTAN personnel visited truckstops in both Virginia and California to review operating procedures and discuss the

concept of the proposed emergency organization with truckstop operators. Mr. Slibeck has subsequently discussed this concept with a wide range of industry representatives.

7.3.2.4 Fuel Industry Personnel.

Fuel industry representatives in Colorado were visited in the course of the postattack study, and were contacted following the development of the prototype plans to check the feasibility of proposed postattack alternatives. These representatives estimated the transportation impacts on fuel movement which would result if Denver pipelines were destroyed, and identified alternative points at which surviving pipelines might be tapped. Their observations led to the suggestion that pipeline terminals on the fringes of anticipated blast areas should be among the first facilities to be hardened against blast effects.

7.4 RECOMMENDATIONS

Additional transportation research that might be considered by DCPA includes:

- A joint venture with NDTA to conduct emergency exercises and develop audio-visual materials in support of the CRP process.

- A study similar to the Volume III truckstop study to assess the role of private truck fleets and their support terminals in time of crisis. These fleets and terminals account for an estimated 32% of the diesel fuel used in intercity cargo transportation, and a larger percentage of intracity fuel consumption.

- A parametric analysis of the implications of wider population dispersal during crisis relocation on transportation and fuel requirements.

- A nationwide commodity movement model to provide a basis for quantifying the increases in transportation distances, vehicle requirements, and fuel consumption resulting from a range of attack patterns.

- Development of a simplified, summarized version of planning guidance, explicitly specifying what is expected of each crisis relocation transportation planner.

APPENDIX A

VEHICLES

TABLE A-1

TRANSIT VEHICLE INVENTORY:

COLORADO SPRINGS AND EL PASO COUNTY

TYPE	NO. OF VEHICLES	SEATING CAPACITY	TOTAL SEATS AVAILABLE
Intercity	9	50	450
Local Bus			
Capacity A	25	46	1,150
Capacity B	6	33	198
School Bus	174	25	4,350
Tour Bus	6	20	120
Van	8	14	112
Limo	3	7	21
Taxicab	44	5	220
TOTALS	275	241	6,621

(Source: Reference 6)

TABLE A-2

COMMON CARRIER CARGO VEHICLE INVENTORY

COLORADO SPRINGS

VEHICLE	AVERAGE NUMBER BY WEIGHT* LIGHT	MEDIUM	HEAVY	TOTAL
TRUCK				
Tank	-	5	2	7
Flat & Rack	-	321	9	330
Van	-	94	36	130
Refrigerator	-	4	-	4
Other	1080	204	1	1285
TOTAL	1080	628	48	1756
TRACTOR UNITS	-	80	35	115
TRAILERS				
Tank	-	52	-	52
Flat and Rack	-	99	7	106
Van	-	37	9	46
Refrigerator	-	4	-	4
Other	-	9	-	9
TOTAL	0	201	16	217
TOTAL VEHICLES	1080	909	99	2088

*Light: Under 10,000 pounds gross vehicle weight (GVW)
Medium: Between 10,000 pounds and 26,000 pounds GVW
Heavy: Over 26,000 pounds GVW

Source: The Industrial Picture - Colorado Springs Chamber of Commerce, Colorado Springs, March, 1973.

TABLE A-3: ESTIMATED MOTOR VEHICLE TRAVEL IN THE UNITED STATES AND RELATED DATA (1973)

ITEM	PASSENGER VEHICLES							CARGO VEHICLES			ALL MOTOR VEHICLES
	PERSONAL PASSENGER VEHICLES			BUSES			ALL PASSENGER VEHICLES	SINGLE-UNIT TRUCKS	COMBI-NATIONS	ALL TRUCKS	
	PASSENGER CARS 2/	MOTOR-CYCLES 2/	ALL PERSONAL PASSENGER VEHICLES	COMMERCIAL	SCHOOL	ALL BUSES					
Motor-vehicle travel:											
(million vehicle-miles)											
Main rural roads			341,633	890	920	1,810	343,443	86,764	32,772	119,536	462,979
Local rural roads			102,631	113	995	1,108	103,739	33,292	1,165	34,457	138,196
All rural roads			444,264	1,003	1,915	2,918	447,182	120,056	33,937	153,993	601,175
Urban streets			592,191	1,545	497	2,042	594,233	99,072	14,082	113,154	707,387
Total travel	1,016,861	19,594	1,036,455	2,548	2,412	4,960	1,041,415	219,128	48,019	267,147	1,308,562
Number of vehicles registered (thousands)	101,762.5	4,356.5	106,119.0	89.5	336.0	425.5	106,544.5	22,205.0	1,027.9	23,232.9	129,777.4
Average miles traveled per vehicle	9,992	4,498	9,767	28,469	7,178	11,662	9,774	9,868	46,716	11,538	10,083
Fuel consumed (million gallons)	77,619	392	78,011	520	327	847	78,858	22,755	8,860	31,615	110,473
Average fuel consumption per vehicle (gallons)	763	90	736	5,810	973	1,991	741	1,025	8,620	1,361	851
Average miles traveled per gallon of fuel consumed	13.10	50.00	13.29	4.90	7.37	5.86	13.21	9.63	5.42	8.45	11.85

1/ For the 50 States and District of Columbia.
2/ Separate estimates of passenger car and motorcycle travel are not available by highway category.

(Source: Federal Highway Administration, Highway Statistics, 1973, U.S. Department of Transportation Washington, D.C.)

APPENDIX B

FUEL

TABLE B-1

DAMAGE ASSESSMENT OF PETROLEUM PRODUCTION AND STORAGE CAPABILITIES
AT THE NATIONAL LEVEL (BASED ON UNCLEX-CHARLIE ATTACK)
(Figures in Hundreds of Barrels)

Category	Preattack Level	Destroyed or Severely Damaged	Accessible for Repair D+180	Accessible for Use		
				D + 1	D + 15	D + 30
PETROLEUM PRODUCTION						
Motor Gasoline	972,121	341,406	280,381	227,243	316,637	336,442
% of Preattack Total	100.0	35.1	28.8	23.4	32.6	34.6
Kerosene	274,817	88,634	76,602	75,335	102,936	106,911
% of Preattack Total	100.0	32.3	27.9	27.4	37.5	38.9
Distillate Fuel Oil	517,905	206,888	173,634	84,018	115,282	129,644
% of Preattack Total	100.0	39.9	33.5	16.2	22.3	25.0
Residual Fuel Oil	173,605	80,555	66,120	14,851	23,348	26,234
% of Preattack Total	100.0	46.4	38.1	8.6	13.4	15.1
Total Production	1,938,448	717,483	596,737	401,447	558,203	599,231
PETROLEUM STORAGE						
Motor Gasoline	1,673,262	599,628	481,073	381,338	533,513	568,162
% of Preattack Total	100.0	35.8	28.8	22.8	31.9	34.0
Kerosene	603,241	198,044	165,253	162,972	224,587	233,779
% of Preattack Total	100.0	32.8	27.4	27.0	37.2	38.8
Distillate Fuel Oil	1,465,572	598,609	492,821	222,444	307,588	350,648
% of Preattack Total	100.0	40.8	33.6	15.2	21.0	23.9
Residual Fuel Oil	450,955	207,791	171,898	39,681	62,083	69,477
% of Preattack Total	100.0	46.1	38.1	8.8	13.8	15.4
LP Gas	214,972	13,365	102,613	83,697	98,219	98,721
% of Preattack Total	100.0	6.2	47.7	38.9	45.7	45.9
Total Storage	4,408,002	1,617,437	1,413,658	890,132	1,225,990	1,320,787

Source: Federal Preparedness Agency, Ready Summary Analysis of Scheduled Availability for for Production (SASAP) Attack UNCLEX-CHARLIE Category EMR Estimated Invent. of Petroleum Prod. (March) National Summary and Category ESP Petroleum Product Storage Capacity National Summary, FPA, General Services Administration, Washington, D.C., October 1977.

TABLE B-2

SUMMARY OF HOST AREA MOTOR FUEL STORAGE CAPACITIES

COMMUNITY	SERVICE STATIONS					BULK DISTRIBUTORS			
	Total Number of Stations	Total Number of Pumps at All Stations	Total Number Dispensing Diesel Fuel	Total Gasoline Storage at All Stations	Total Diesel Fuel Storage at All Stations	Total No. of Bulk Gasoline Distributors	Total No. of Bulk Diesel Fuel Distributors	Total Gasoline Storage Capacity of All Distributors	Total Diesel Fuel Storage of All Distributors
Antero Function	--	--	--	--	--	--	--	--	--
Buena Vista-Johnson Corne	15	69	1	205,830	2,000	2	2	24,000	24,000
Villa Grove	1	2		1,500					
Moffat	--	--	--	--	--	--	--	--	--
Hooper	2	2	--	4,060	--	--	--	--	--
Mosca	2	5	--	15,300	--	--	--	--	--
Alamosa	33	136	19	498,730	114,285	9	9	345,000	195,000
Saguache	5	22	--	67,320	--	2	2	54,900	24,000
Center	7	22	2	67,320	12,030	--	--	--	--
Monte Vista	23	104	14	107,334	+74,105				
Del Norte	10	47	3	32,852	+ 6,015				
South Fork	7	17	1	26,500	+ 850				
Pagosa Springs	9	41	--	122,000	--				
Bay Field-Gem Village	12	34	--	60,000	--				
Durango	31	25	6	443,470	58,015	6	6	281,000	65,000
Florence	11	28	5	85,680	30,075	2	2	63,285	6,700
Canon City	39	178	5	538,560	30,075	6	6	222,000	9[illegible],000
Texas Creek	1	2	--	6,120	--	--	--	--	--
Cotopaxi	3	8	1	24,480	6,015	--	--	--	--
Salida	27	117	5	301,200	32,215	--	--	--	--
Poncha Springs	7	30	3	64,500	10,500	10	10	165,000	89,000
Garfield	2	6	--	6,500	--	--	--	--	--
Gunnison	17	112	6	302,940	36,090	5	5	56,000	16,600
Woodland Park	8	43	3	131,580	18,045	--	--	--	--
Divide	3	14	1	42,840	6,015	1	1	4,000	7,000
Cripple Creek	5	15	--	45,900	--	--	--	--	--
Victor	2	4	--	12,240	--	1	1	9,000	6,000
Florissant	1	5	--	15,300	--	--	--	--	--
Lake George	2	4	--	12,240	--	--	--	--	--
Hartsel	1	2	--	6,120	--	1	1	12,000	10,000
TOTAL	286	1,094	75	5,248,466	436,330	45	45	1,236,185	541,300

TABLE B-3

REPAIR REQUIREMENTS BY REFINERY TYPE

Refinery Type	Capacity B/D	Labor in Man-Days			
		0.5 psi	1 psi	5 psi	10 psi
Large fuel	78,000	36,000	128,000	178,000	292,000
	150,000*	70,000	245,000	341,000	556,000
Small fuel	24,000	7,000	24,000	36,000	77,000
Complete processing	194,000	82,000	289,000	402,000	640,000
Asphalt	12,000	3,000	11,000	16,000	28,000
	14,000*	4,000	13,000	18,000	31,000
Asphalt and lube	7,000	2,000	6,000	10,000	22,000
Lube	4,000	1,000	4,000	6,000	18,000
	27,000*	7,000	25,000	37,000	72,000

*Included to determine the effect of refinery size variation on repair equipment.

Source: Stephens, Maynard M., Vulnerability of Petroleum Systems, DAHC 20-70-C-0316, DCPA Work Unit 4362A, May 1973.

APPENDIX C

RELOCATION OF ORGANIZATIONS

RELOCATION OF ORGANIZATIONS

A. Necessary Risk Area Operations

Organization	Employees	Employees and Dependents	Relocation Site
City-County D&C	36	114	El Paso
Mountain States T&T	750	1,995	Fremont
American Tel. & Tel.	80	254	Fremont
Western Union Tel. Co.	105	333	Fremont
Station KPIK	21	67	Teller
Station KRDO	30	95	Fremont
Station KVOR	26	82	Fremont
Station KSSS	30	95	Fremont
Station KKTV	34	108	El Paso
Colorado Springs Sun	175	555	Teller
Colo. Spgs. Gazette-Telegraph	32	101	Teller
Colorado Springs Police	48	152	El Paso
Fountain Police Dept.	13	42	Fremont
Manitou Spgs. Police Dept.	14	44	Teller
Colorado Spgs. Traffic Eng.	11	34	El Paso
Civil Air Patrol	12	37	Fremont
Colorado Springs Fire Dept.	114	362	El Paso
Fountain Fire Dept.	10	32	Fremont
Manitou Spgs. Fire Dept.	11	35	Teller
Broadmoor Fire Prot. Dist.	12	38	Fremont
E&E Ambulance Company	50	155	Fremont
Mountain Valley Ambulance	40	126	El Paso
Penrose Hospital	215	682	Teller
Emory John Brady Hospital	80	254	Teller
Pikes Peak Chapter-ARC	20	63	El Paso
Myron Stratton Home	75	238	Fremont
Broadmoor Hotel Nursing	130	412	Fremont
City-County Health Dept.	25	79	El Paso
Colorado Spgs. Street Div.	10	32	El Paso
El Paso Co. Coroner	10	33	Teller
Evergreen Cemetery	12	38	Teller
Fairview Cemetery	8	25	Teller
Evergreen Funeral Home	9	29	Teller
El Paso Co. Social Serv.	200	634	El Paso
Colorado College	12	37	Fremont
Dott's Restaurant	18	57	Fremont

(Appendix C, Continued)

Organization	Employees	Employees and Dependents	Relocation Site
Hilton Inn	120	380	Fremont
Airport Admin. Off.	30	95	El Paso
Colo. Spgs. Electric Div.	80	254	Teller
Colo. Spgs. Sewer Div.	25	79	Fremont
Colo. Spgs. Water Div.	56	178	El Paso
Colo. Spgs. Gas Div.	24	76	Teller
Colorado Interstate Gas Co.	191	605	El Paso
Colo. Spgs. Purchasing Dept.	38	120	El Paso
Colo. Spgs. Planning Off.	14	44	El Paso
Colo. Spgs. Clerk	14	46	El Paso
El Paso Co. Clerk	11	34	El Paso
Colo. Spgs. Park & Rec.	40	126	El Paso
U.S. Postal Service	244	773	Teller
Colo. Spgs. Garage	10	32	El Paso
Airport Limousine Serv.	14	45	Fremont
Bessemer Bus Company	10	32	Fremont
Yellow Cab Co.	75	238	Fremont
Colorado Springs Coach	40	130	Fremont
Gray Line of Colo. Spgs.	45	143	Teller
Dalby Transfer & Storage	24	75	Fremont
Cowen Transfer & Storage	37	116	Fremont
Weicker Transfer and Stor.	67	212	Fremont
United Parcel Service	133	422	Teller
Chicago Rock Island RR	108	342	Teller
Santa Fe RR	198	627	Fremont
Wyco Pipeline Co.	15	49	Fremont
Petco Inc.	15	64	Fremont
Continental Oil Co.	8	34	Fremont
Hellum's Skelly Service	4	13	El Paso
Hill Oil Co.	6	19	Fremont
N. Nevada Shamrock	5	16	El Paso
Joe Buan Texaco	2	6	El Paso
Lucy's Skelly	4	13	El Paso
31st Street Standard	4	12	Teller
Don's Texaco	5	16	Teller
Holland Park Mobil	2	7	El Paso
WW Gas Ranch	12	38	Fremont
Court House Chevron	3	10	Fremont
College Chevron	2	6	Fremont

(Appendix C, Continued)

Organization	Employees	Employees and Dependents	Relocation Site
Colo. Spgs. Public Works Dept.	26	82	El Paso
Colorado Springs Engineer	15	48	El Paso
Defense Supply Agency	40	127	Teller
Sinton Dairy	158	501	El Paso
Colorado Springs Controller	9	28	El Paso
Colorado Springs Treasurer	6	21	El Paso
El Paso Co. Treasurer	4	14	El Paso
Internal Revenue Service	17	54	El Paso
Colo. Spgs. National Bank	22	70	Teller
Exchange National Bank	27	86	Teller
First National Bank	16	51	Teller
Northern National Bank	17	54	Teller
Pikes Peak National Bank	15	48	Fremont
Western National Bank	17	54	Fremont
Bank Clearing House	35	111	Fremont
Federal Aviation Admin.	80	367	El Paso
National Weather Service	85	269	El Paso

(Source: Reference 20)

APPENDIX D

KEY COLORADO TRANSPORTATION FACILITIES WITH BLAST OVERPRESSURE

TRUCK AND BUS TERMINALS

NUMBER	NAME	ADDRESS	CITY	COUNTY	SIC CODE	EMPLOYMENT RANGE	BLAST OVERPRESSURE (psi)
42	Colorado Cartage Co.	5275 Quebec	Denver	Adams	4210		10 - 15
43	Petco, Inc.	7627 Dahlia	Denver	Adams	4212		5 - 10
44	Ruan Transport Co.	7340 Brighton Blvd.	Denver	Adams	4212		5 - 10
45	Ward Transport	5901 Dexter	Denver	Adams	4210		10 - 15
46	Amick North America	1029 Santa Fe Dr.	Denver	Denver	4210		10 - 15
47	Capitol Hill Transfer	4206 Madison	Denver	Denver	4210		30 - 35
48	Groendyke Transport Inc.	E. 52nd Ave.	Denver	Denver	4212		20 - 25
49	Colorado Transit Management Inc.	1210 S. Hancock	Colo. Springs	El Paso	4171		5 - 10
50	Cowen	3111 Stone	Colo. Springs	El Paso	4210		5 - 10
51	Dalby (Mayflower)	641 Winters Dr.	Colo. Springs	El Paso	4210		2 - 5
52	Weicker (Allied)	205 W. Rio Grande	Colo. Springs	El Paso	4210		2 - 5

RAILROADS (TERMINALS, YARDS, SHOPS & STATIONS)

NUMBER	NAME	ADDRESS	CITY	COUNTY	SIC CODE	EMPLOYMENT RANGE	BLAST OVERPRESSURE (psi)
34	Atchison, Topeka & Santa Fe	5871 Broadway	Denver	Denver			10 - 15
35	Colorado and Southern	11th St. and Wewatta St.	Denver	Denver			30 - 35
36	Denver Rio Grande & Western	1570 13th Ave.	Denver	Denver			15 - 20
37	Rock Island Lines	Union Station 1701 Wynkoop	Denver	Denver			10 - 15
38	Union Pacific	40th Ave. & High St.	Denver	Denver			30 - 35
39	Santa Fe	539 E. Pikes Peak Ave.	Colo. Springs	El Paso			20 - 25
40	Rock Island Lines	112 W. Pikes Peak Ave.	Colo. Springs	El Paso			5 - 10
41	Denver Rio Grande & Western	112 W. Pikes Peak Ave.	Colo. Springs	El Paso			5 - 10

PRIMARY PETROLEUM FACILITIES

NUMBER	NAME	ADDRESS	CITY	COUNTY	SIC CODE	EMPLOYMENT RANGE	BLAST OVERPRESSURE (psi)
	Refineries						
1	Conoco	5801 Brighton	Denver	Adams			10 - 15
2	Refinery Corp.	5800 Brighton	Denver	Adams			10 - 15
3	Gary Western	West of Fruita	Fruita	Mesa			< 1
	Pipelines						
	Wyco						
4	Denver	8160 Leyden St.	Denver	Adams			5 - 10
5	Fountain	South of Fountain	Fountain	El Paso			1 - 2
6	Medicine Bow	8581 E. 96th Ave.	Denver	Adams			5 - 10
		15,000 E. Smith Rd.	Denver	Adams			
	Phillips-Shamrock						
7	Diamond Shamrock Terminal	3960 E. 56th Ave.	Denver	Adams			15 - 20
8	Phillips Petroleum	East of La Junta	La Junta	Otero			2 - 5

SECONDARY BULK PETROLEUM STORAGE

NUMBER	NAME	ADDRESS	CITY	COUNTY	SIC CODE	EMPLOYMENT RANGE	BLAST OVERPRESSURE (psi)
9	Chevron	5201 E. 48th Ave.	Denver	Adams			15 - 20
10	Harpel Oil Co.	5480 Brighton Blvd.	Denver	Adams			15 - 20
11	Diamond Gas & Fuel Co.	4101 S. Santa Fe Dr	Denver	Arapahoe			2 - 5
12	Continental Oil Co.	408 Bear Creek Ave.	Denver	Denver			2 - 5
13	Exxon	750 W. Hampton	Denver	Denver			5 - 10
14	Green Bros. Oil Plant (Chevron)	5335 Harrison	Denver	Denver			15 - 20
15	Husky Oil Co.	4080 Gloveville Rd.	Denver	Denver			15 - 20
16	Husky Oil Co.	600 S. Cherry	Denver	Denver			10 - 15
17	Mobil Oil	4545 Holly	Denver	Denver			15 - 20
18	Acorn Petroleum	232 South 8th	Colo. Springs	El Paso			2 - 5
19	Chevron	529 S. Sahwatch	Colo. Springs	El Paso			2 - 5
20	Chief Petroleum Co.	301 South 10th	Colo. Springs	El Paso			5 - 10
21	Cliff Brice Shamrock	712 E. Fillmore	Colo. Springs	El Paso			5 - 10
22	Colonial Conoco Distributors	925 Cucharras	Colo. Springs	El Paso			2 - 5
23	Continental Oil Co.	212 S. 12th St.	Colo. Springs	El Paso			2 - 5
24	Davidson Oil Co.	1705 W. Unitah	Colo. Springs	El Paso			2 - 5
25	Hill Oil Co.	2540 Carmel	Colo. Springs	El Paso			10 - 15
26	Lory Oil Co.	E. Platte & Iowa	Colo. Springs	El Paso			40 - 45
27	K & L Oil Co.	3305 N. Hancock	Colo. Springs	El Paso			5 - 10
28	Kindred Oil Co.	615 S. 29th	Colo. Springs	El Paso			2 - 5
29	Phillips	Airport	Colo. Springs	El Paso			10 - 15
30	Scott Oil Co.	2961 N. Nevada Ave.	Colo. Springs	El Paso			5 - 10
31	Standard Oil Co.	230 E. Polk	Colo. Springs	El Paso			2 - 5
32	Wholesale Oil Co.	3313 W. Colorado	Colo. Springs	El Paso			1 - 2
33	Continental Oil Co.	210 Depot	Golden	Jefferson			1 - 2

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This study extends previous research into the transportation implications of a crisis relocation by (1) investigating the effects of a nuclear attack on the reconfigured transportation system and the relocated population, (2) identifying and evaluating alternative means of providing transportation system support to the relocated survivors of such an attack, and (3) reviewing existing relocation guidance in the light of probable postattack consequences. This research evaluates the problem of providing transportation system support following both a relocation effort and a nuclear attack, and systematically proposes and evaluates alternative solutions to this problem. Where applicable, the proposed solutions are examined in detail in a case study of Colorado Springs, Colorado.

The study addresses the principal components of the transportation system: vehicles, road and rail networks, and fuel. Severe fuel shortages can be anticipated following a nuclear attack, and these shortages will be more critical than either vehicle losses or road and rail network damage in constraining postattack movement.

On the basis of the case study, the transportation elements of prototype crisis relocation plans for the State of Colorado, the Colorado Springs area, and a representative reception area (Fremont County, Colorado) have been revised and updated to reflect postattack concerns. Guidelines for state and local relocation planners in other areas have been similarly updated.

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